CHEMICAL ENGINEERING
March 2024
ESSENTIALS FOR THE CPI PROFESSIONAL
www.chemengonline.com

Calibration of Scales

page 23

Flowmeters
Heat Exchangers
Additive Manufacturing
Electrical Safety
Pipes, Tubes and Fittings
Industrial Combustion

Access Intelligence

CHEMICAL ENGINEERING
ESSENTIALS FOR THE CPI PROFESSIONAL
www.chemengonline.com

March 2024 Volume 131 | no. 3

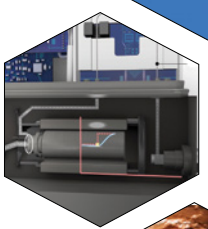
Cover Story

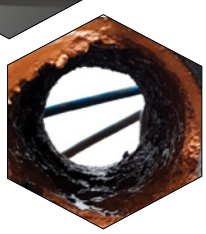
In the News


23


13

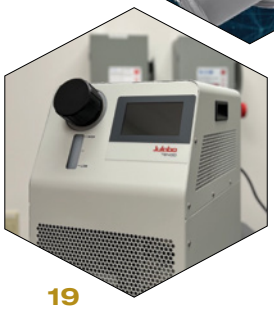
Technical and Practical


29


33

39

17



19

Equipment and Services

Departments

Advertisers

Chemical Connections

Join the *Chemical Engineering* Magazine LinkedIn Group

Visit us on www.chemengonline.com for more articles, Latest News, New Products, Webinars, Test your Knowledge Quizzes, Bookshelf and more

Coming in April

Look for: **Feature Reports** on Mixing; and Industrial Gases; A **Focus** on Valves; A **Solids Processing** article on Material Transfer; a **Newsfront** on Seals and Gaskets; **New Products**; and much more

Cover design: Tara Bekman
Cover photo: Shutterstock

CHEMICAL ENGINEERING
ESSENTIALS FOR THE CPI PROFESSIONAL

HEADQUARTERS

40 Wall Street, 16th floor, New York, NY 10005, U.S.
Tel: 212-621-4900
Fax: 212-621-4694

EUROPEAN EDITORIAL OFFICES

Zeilweg 44, D-60439 Frankfurt am Main, Germany
Tel: 49-69-9573-8296
Fax: 49-69-5700-2484

CIRCULATION REQUESTS:

Tel: 800-777-5006
Fax: 301-309-3847
Chemical Engineering, 9211 Corporate Blvd.,
4th Floor, Rockville, MD 20850
email: clientservices@accessintel.com

ADVERTISING REQUESTS: SEE P. 46

ACCESS INTELLIGENCE, LLC

HEATHER FARLEY
Chief Executive Officer

JOHN B. SUTTON
Chief Financial Officer

MACY L. FECTO
Chief People Officer

JENNIFER SCHWARTZ
Divisional President,
Industry & Infrastructure

LORI JENKS
Senior Vice President,
Event Operations

MICHAEL KRAUS
Vice President,
Production, Digital Media & Design

JONATHAN RAY
Vice President, Digital

TINA GARRITY
Vice President of Finance

DANIEL J. MEYER
Vice President,
Corporate Controller

STUART BONNER
Vice President,
Marketing Operations

MICHELLE LEVY
Vice President,
Administration

Access Intelligence
9211 Corporate Blvd., 4th Floor
Rockville, MD 20850-3240
www.accessintel.com

Editor's Page

Science scores

Last month's Super Bowl LVIII did not disappoint. Along with the exciting overtime finish, record-breaking field goals and more, once again advertisers showcased their special commercials created specifically for this annual championship sporting event. The commercials tend to generate almost as much anticipation as the game itself. With about 123.4 million viewers this year, the game was reportedly the most-watched television show in history, exceeding last year's record high. Undoubtedly Super Bowl advertisements get tremendous exposure.

Amid the variety of commercials ranging from serious to funny to silly, and featuring numerous famous entertainers and sports figures, as well as a talking cat (meow can sound like mayo), one ad stood out to me: Pfizer's "Here's to Science." [*1*]

This commercial has an upbeat tone, with busts, portraits and pictures of some of the superstars of science — Archimedes, Hippocrates, Galileo, Copernicus, Newton and Einstein — seemingly singing along to Queen's "Don't Stop Me Now." Along with these well-known figures and the founders of Pfizer, Charles Pfizer and Charles Erhart, the fast-paced commercial flashes glimpses of other notable scientists, whose names may not be as familiar:

Rosalind Franklin (1920–1958) – A British chemist who early in her career studied the physical chemistry of carbon and coal. She studied and applied X-ray diffraction techniques to study DNA and is probably best known for her contributions to understanding the structure of DNA. She also contributed to the understanding of the structure of viruses.

Marie Maynard Daly (1921–2003) – Daly was an American biochemist whose research focused on practical applications of nutrition and health. She is known for uncovering the relationship between cholesterol and clogged arteries. She made history by becoming the first African-American woman to earn a Ph.D. in chemistry.

Benjamin Banneker (1731–1806) – Banneker was a self-taught mathematician and astronomer who gained fame by building a wooden clock, thought to be the first built in America, that kept precise time for decades. He was able to make astronomical calculations that enabled him to forecast a solar eclipse. He was one of the first African Americans to gain distinction as a scientist.

Mary Somerville (1780–1872) – A trailblazer for women in science, Somerville studied mathematics and wrote numerous influential works. One of her writings is said to have contributed to the discovery of the planet Neptune.

Katalin Karikó and Drew Weissman – Karikó is a biochemist and researcher and Weissman is a physician and researcher, both at Penn Medicine. They had discovered a way to modify Messenger RNA (mRNA), and later found a way to package the mRNA in lipid nanoparticles, making it possible to deploy the mRNA as a vaccine. Karikó and Weissman were jointly awarded the 2023 Nobel Prize in Medicine for their work on mRNA that enabled the development of vaccines against COVID-19.

I was glad to see science showcased on the big stage of the popular television broadcast with scientists as the celebrities. I look forward to more instances where science and engineering can be brought to the general public in a positive, upbeat way. ■

Dorothy Lozowski, Editorial Director

1. Pfizer's commercial "Here's to Science" is available at www.youtube.com/watch?v=fwvjimuwVyY

Upcycling polyethylene into thermoplastic polyurethane

A first-of-its-kind plastics-recycling technology is being demonstrated in a new pilot plant in India. Novoloop (Menlo Park, Calif.; www.novoloop.com), in partnership with Aether Industries (Gujarat, India; www.aether.co.in), is developing an integrated pilot plant to scale up Novoloop's Lifecycling technology, which is said to be the first industrial process to make thermoplastic polyurethane (TPU) by oxidizing polyethylene (PE) waste. Lifecycling involves a controlled oxidation process (diagram), which oxidizes PE waste into diacid monomers that can act as a direct replacement for the fossil-based adipic acid traditionally used in TPU production. "While pyrolysis produces oils that can displace fossil-fuel feedstocks, Lifecycling produces higher-value products further down in the petrochemical value chain," says Jennifer Le Roy, chief technology officer of Novoloop.

Current scaleup efforts are focused on PE waste from a variety of post-consumer sources. The Lifecycling process can chemically upgrade hard-to-recycle waste streams, such as highly degraded and oxidized films, which typically cannot be processed via mechanical recycling or pyrolysis. Beyond TPU, the diacid monomers can be used to make polyesters, polyamides and other performance materials.

By the end of 2024, Novoloop expects the new pilot plant to reach a plastics-processing capacity of around 70 metric tons per year (m.t./yr). "The integrated pilot plant marks a major leap forward in Novoloop's journey toward commercial success. This crucial step will demonstrate long-term continuous production in an operational environment, paving the way for full-scale operation," says Nedim Hasanbegovic, vice president of engineering at Novoloop.

Novoloop

A new project targeting emissions-free pulping

The Emission Free Pulping program aims to significantly reduce biomass burning and increase the product yield of wood material used for pulping from approximately 50 to around 70%. The five-year, €15-million program is jointly led by VTT Technical Research Centre of Finland Ltd. (Espoo; www.vttresearch.com) and RISE Research Institutes of Sweden AB (Gothenburg; Sweden; www.ri.se), and includes 10 participants from research organizations, universities and industry.

The program intends to find ways to improve energy efficiency, enhance the efficiency of wood usage and conversion to products, achieve emission-free pulping (especially CO_2 emissions) and significantly reduce water usage in the processes.

"Due to the limited nature of forest resources, the growth opportunities for the industry are constrained," says Atte Virtanen, vice president of biomaterial processing and products at VTT. "Moreover, the burning of biomass in the pulping process results in the emission of biogenic CO_2. To significantly enhance resource efficiency and increase the value added from wood, revising the chemical processes and unit operations used in the pulping process is essential," Virtanen says.

Andritz AG, Arauco, Metsä Group, Stora Enso Oyj and Valmet Oyj have committed to a five-year collaboration with the research organizations and universities for this program. In addition, the project involves significant contributions from Aalto University, Chalmers University of Technology, KTH Royal Institute of Technology, LUT University, Mid Sweden University, University of Helsinki, University of Oulu and Åbo Akademi University.

The program has been granted substantial funding from Business Finland, amounting to over €5 million over a three-year period, with additional funding contributions from industrial partners.

Edited by:
Gerald Ondrey

WASTE HEAT

Last month, Evonik Industries AG (Essen; www.evonik.com) and Uniper (Düsseldorf, both Germany; www.uniper.energy) launched the Technical Options for Thermal Energy Recovery (TORTE) project in Gelsenkirchen. As one of the first phases of Evonik's Herne Green Deal to sustainably transform the Herne chemical site, the TORTE project will feed industrial waste heat from isophorone production into the district heating network. Around 1,000 homes in the Ruhr region will be supplied by the end of 2024.

To recover this industrial low-temperature waste heat, Uniper has installed a large onsite heat pump to feed up to 1.5 MW of heat into the district heating network to supply local customers. This sustainably recovered heat from the Herne site will help Uniper to reduce its emissions by 1,750 ton/yr of CO_2. The project also supports Evonik's sustainability ambitions to reduce carbon emissions and its use of fossil resources at its sites.

LIMESCALE

A research team from ETH Zurich (Switzerland; www.ethz.ch) and the University of California, Berkeley (www.berkeley.edu) has developed a limescale-repellent coating that prevents the adhesion of limescale crystals. The researchers examined — at the microscopic level — the interactions among individual growing limescale crystals, the surrounding water flow and the surface. Based on this, the team developed several coatings from various soft materials and tested them in the laboratory at ETH Zurich.

The most effective coating

(Continues on p. 6)

was a polymer hydrogel, the surface of which is covered in tiny ridges formed in microtextured molds that were fabricated by photolithography.

In boilers, the riblets ensure that the limescale crystals have less contact with the surface, so they cannot adhere and are thus easier to remove; water flowing over the hydrogel and through the ribbed structure carries them away. While the coating can't fully prevent limescale crystals from forming, the constant passive removal of the microscopic crystals stops them growing together to form a layer.

Rather than applying for a patent for their development, the researchers have deliberately decided in favor of publication, which appeared in a recent issue *Science Advances*. This means that all interested parties are free to further develop and utilize the new coating.

COPPER RECOVERY

Last month, BASF SE (Ludwigshafen, Germany; www.basf.com) and hydroGeophysics Inc. (HGI; Tucson, Ariz.; www.hgiworld.com) announced an exclusive partnership aimed at combining expertise in mineral processing, hydrometallurgy and deep-well injection. The collaboration aims to optimize copper extraction in the mining industry by utilizing HGI's geophysical techniques to identify areas within the heap that currently offer poor recovery and will involve the design and implementation of a deep-well injection program, incorporating BASF's LixTRA leach aid to facilitate a significant uplift in copper extraction.

The heap leach process, which involves piling low-grade ores onto a liner and dripping a lixiviant (usually acid) over the heap to dissolve copper into solution,

(Continues on p. 8)

Harvesting water and minerals from waste slurries with supercritical water oxidation

A wastewater treatment plant operated by Orange County (Calif.) Sanitation District is the site of the first installment, at a commercial facility, of a new supercritical water oxidation (SCWO) technology capable of producing clean water and minerals from waste slurries. The clean-technology startup 374Water Inc. (Durham, N.C.; www.374water.com), originating from Duke University, developed the technology, known as AirSCWO.

Supercritical water processes for waste destruction involve elevating water above its critical point (heated above 374°C and pressurized above 221 bars) to take advantage of the unique properties of water under those conditions. "Water beyond its critical point exhibits properties that are opposite those of water at ambient temperature and pressure," explains Naomi Senehi, applications engineer at 374Water. "For example, organic materials and gases like oxygen are highly soluble in supercritical water, while inorganic materials are not."

In the AirSCWO process, a pumpable slurry of waste is mixed with ambient air and preheated before entering a pipe reactor, where rapid oxidation reactions dissociate organic waste into inorganic compounds, CO_2 and water. A pressurized stream of vaporized water exits the reactor and enters an expander, which generates distilled water and electricity, while a liquid stream from the reactor carries minerals, such as phosphates, sulfates and metal oxides for potential recovery. Excess heat, generated by the exothermic oxidation reactions, is used to preheat the slurry.

374Water's process aims to overcome certain technical challenges associated with existing SCWO systems. The company holds patents on a corrosion-resistant alloy for the reactor that allows the reactor to withstand corrosion that has proved problematic for some previous SCWO efforts. Also, the AirSCWO process is engineered for the use of ambient air as the oxidant, eliminating the need for compressed oxygen, Senehi points out, which reduces cost and improves safety.

AirSCWO units are housed in 40-ft shipping containers, which can be stacked together to increase scale. Each unit is capable of processing 6 wet tons of sludge per day, Senehi says.

Accelerating scaleup for battery-grade silicon-enhanced graphite

Incorporating silicon into the anodes of electric vehicle (EV) batteries can result in lighter and longer-range batteries. However, this process requires large volumes of silane (SiH_4) gas, the vast majority of which is currently produced in China. Now, a new partnership between OneD Battery Sciences (Palo Alto, Calif.; www.onedsinanode.com) and Koch Modular Process Systems, LLC (Paramus, N.J.; www.kochmodular.com) is bringing together onsite silane production with the manufacture of silicon-graphite anode materials to create the first integrated North American plant to produce silicon-graphite anode materials. The key to this project is a unique modular process to produce silane developed by Koch Modular. "Silane is typically shipped in tube trailers, which weigh a huge amount compared to the volume of silane gas they carry, making it very expensive to ship at the quantities required to make batteries," explains George Schlowsky, president of Koch Modular. By integrating modular silane production into OneD's Sinanode process for converting silane into nanosilicon inside EV-grade graphite materials, battery production costs can be significantly reduced. In addition, range and charging speed are increased.

One key element of the Sinanode technology is a low-cost catalyst to decompose the silane, extracting the silicon and exhausting the hydrogen. "We have designed a way to make trillions of uniform nanoparticles of copper oxide floating in deionized water, at an incredibly low cost," explains Vincent Pluvinage, CEO of OneD. When mixed with graphite, the catalyst will deposit onto the graphite, leading to very fast decomposition of the silane. Another key element of the Sinanode process is that it employs inexpensive equipment that is widely used in the solar industry. "In the part of the machine where you would normally insert a solar-cell wafer, we put a reactor with catalyzed graphite where we inject silane and nitrogen, and the silane decomposes into nano-silicon inside the graphite pores," says Pluvinage.

The new integrated plant is anticipated to produce around 20,000 tons/yr of silicon-enhanced EV-grade graphite, eventually scaling up to 40,000 tons/yr. OneD has been operating a single-tube reactor since 2018, producing up to several tons per year, and in April, the company is starting up a 100-ton/yr unit in Moses Lake, Wash.

offers a cost-effective method for copper extraction. However, the non-uniformity of heaps often leads to areas of ore compaction and poor lixiviant permeation, resulting in suboptimal recovery of metal.

HGI employs geophysical technologies to characterize the structural components of the heaps, enabling the design, operation and monitoring of targeted lixiviant injection wells. By adding BASF's LixTRA leach aid, greater ore-lixiviant contact is made, which ultimately leads to higher copper dissolution and increased metal recovery. Initial results from a client's site have demonstrated a 20% increase in copper recovery during the trial period, prompting further testing on a larger scale to quantify the benefits.

CERAMICS

Earlier this year, the E.U. Horizon project eLITHE (Electrification of ceramic industries high temperature heating equipment) was launched to advance the decarbonization of the ceramics industry. The four-year project is coordinated by Fundación CIRCE (Zaragoza, Spain; www.fcirce.es), with participation of experts in the ceramics and electrification sectors — 18 partners from nine European countries. It will showcase innovative, sustainable and cost-effective pathways for electrifying high-temperature thermal processes, such as melting, calcination and firing.

Among the new technologies being demonstrated are microwave-assisted heating at Mytilineos S.A. (Ma-

(Continues on p. 9)

A modularized method to make low-carbon methanol

Stranded methane in waste streams and flare gases at remote processing sites is a promising untapped resource. Now, with a new modular technology, companies can take advantage of this hydrocarbon-containing stream while also reducing their methane emissions. M2X Energy (Rockledge, Fla.; www.m2x.energy) has developed a transportable production unit that converts stranded methane-rich gases into low-carbon methanol. "M2X Energy's system is a 'chemical plant on wheels' that takes, as its target feedstock, the methane-rich gas typically derived from waste streams from various industries. The transportability of our units allows a streamlined process that provides a minimally invasive and economically advantageous outlet for these waste gases," says Edwin Yik, principal engineer at M2X Energy.

At the heart of the unit is a patented engine-reformer technology that transforms the feed gas into synthesis gas (syngas) via non-catalytic partial oxidation. "This syngas intermediate is then compressed to pressures conducive for catalytic methanol synthesis. A boiling-water reactor, containing a fixed-catalyst bed, then converts this compressed syngas into crude methanol via CO and CO_2 hydrogenation chemistries," explains Yik. By creatively adapting a conventional internal-combustion engine, the technology boasts low operating expenses and the ability to readily accept the variations in inlet gas flows and compositions that can occur in industrial waste-gas streams.

The methanol produced in field tests exhibited over 95% purity across a wide range of inlet gas-feed compositions, and the unit is designed to handle trace contaminants, such as hydrogen sulfide, which may negatively impact the catalytic process. A commercial-scale, full-system modular unit was commissioned in 2023, which has been deployed and tested at sites in North Carolina and North Dakota, and the core engine-reformer technology has been further validated on a diverse range of feed gases at oil-and-gas sites in Texas and Oklahoma. The next phase of development will build upon these trials to further improve process performance, including a new joint-development partnership with global manufacturer SCG Chemicals plc (Bangkok, Thailand) to further optimize the catalytic methanol-synthesis steps of the process.

Autonomous synthesis robot uses AI to speed up chemical discovery

Chemists at the University of Amsterdam (UvA; the Netherlands; www.uva.nl) have developed an autonomous chemical-synthesis robot with an integrated artificial-intelligence (AI)-driven machine learning unit. Dubbed "RoboChem," the benchtop device can outperform a human chemist in terms of speed and accuracy, while also displaying a high level of ingenuity. Said to be the first of its kind, RoboChem could significantly accelerate chemical discovery of molecules for pharmaceutical and many other applications. RoboChem's first results were published recently in *Science*.

RoboChem was developed by the group of professor Timothy Noël at UvA's Van 't Hoff Institute for Molecular Sciences (www.hims.uva.nl). Their *Science* article shows that RoboChem can perform a variety of reactions while producing minimal amounts of waste. Working autonomously around the clock, the system delivers results quickly and tirelessly. "In a week, we can optimize the synthesis of about ten to twenty molecules," says Noël. "This would take a PhD student several months." The robot not only yields the best reaction conditions, but also provides the settings for scaleup. "This means we can produce quantities that are directly relevant for suppliers to the pharmaceutical industry, for example."

In RoboChem, a robotic needle collects starting materials and mixes these together in volumes of just over 0.5 mL. These then flow through the tubing system to the reactor, where the light from powerful light emitting diodes (LEDs) triggers the molecular conversion by activating a photocatalyst included in the reaction mixture. The flow then continues towards an automated nuclear magnetic resonance (NMR) spectrometer that identifies the transformed molecules. These data are fed back in real time to the computer that controls RoboChem, which processes the information using AI. "We use a machine learning algorithm that autonomously determines which reactions to perform. It always aims for the optimal outcome and constantly refines its understanding of the chemistry." explains Noël.

The researchers also used RoboChem to replicate previous research published in four randomly selected papers. They then determined whether Robochem produced the same — or better — results. "In about 80% of the cases, the system produced better yields. For the other 20%, the results were similar," Noël says.

Biomanufacturing process minimizes CO_2 loss in fermentation

Fermentation processes provide essential pathways for many chemicals, but are often hampered by high costs and low yields due to CO_2 losses. To overcome these concerns, ZymoChem (San Leandro, Calif.; www.zymochem.com) has developed the patented Carbon Conservation fermentation technology. "Typically, microbes utilizing naturally occurring pathways lose at least one-third of the carbon inputs in the form of CO_2. To avoid this, our proprietary microbes utilize a redesigned biosynthetic pathway that results in a variety of products without losing CO_2. Because of this development, the process is more efficient in the use of feedstocks, resulting in a 30–50% increase in theoretical yields," explains Harshal Chokhawala, CEO of ZymoChem.

While the platform can operate with a variety of renewable feedstocks, including crude glycerol and plant-based dextrose, to make a wide range of products, ZymoChem is focused on producing bio-based and biodegradable superabsorbent polymers, precursors for bio-based nylons, coatings and textile materials. While the platform's output is dynamic, it relies on the same initial steps for all products. "The Carbon Conservation biosynthetic pathway involves a sequence of 7–12 non-naturally occurring reactions. The first seven are shared regardless of product, and by tailoring the remaining steps, different products can be created. We add proprietary chemistry on top of our biological platform to create specific performance attributes, including biodegradability," says Chokhawala.

Because ZymoChem's fermentation process is conducted in an environment that requires little or no air, the complexities traditionally associated with mass- and heat-transfer in commercial-scale fermenters are greatly reduced, enabling the Carbon Conservation technology to operate efficiently at higher scales. "Additionally, operating in an anaerobic environment does not require energy for aeration or cooling, as in other fermentation processes, so our costs are further lowered to either parity, or in some cases, below the costs of incumbent fossil-derived products," adds Chokhawala.

rousi, Greece), flexible hybrid H_2 burners at the Brick and Tile Research Institute (IZF; (Essen, Germany) and electric technologies at Torrecid S.A. (Castellón, Spain). Its enabling technologies will involve smart control through digital twins, novel sensors and materials, and high-temperature energy storage.

PLASTICS

A team of scientists from Nanyang Technological University, Singapore (NTU Singapore; www.ntu.edu.sg) has developed an artificial "worm gut" to break down plastics. By feeding worms with plastics and cultivating microbes found in their guts, researchers from NTU's School of Civil and Environmental Engineering and Singapore Center for Envi-

(Continues on p. 10)

ronmental Life Sciences Engineering have demonstrated a new method to accelerate plastic biodegradation.

Previous studies have shown that *Zophobas atratus* worms — the larvae of the darkling beetle commonly sold as pet food and known as "superworms" for their nutritional value — can survive on a diet of plastic, because its gut contains bacteria capable of breaking down common types of plastic. However, their use in plastics processing has been impractical due to the slow rate of feeding and worm maintenance.

NTU scientists have now demonstrated a way to overcome these challenges by isolating the worm's gut bacteria and using them to do the job without the need for large-scale worm breeding.

In the study, published in *Environment International*, the NTU scientists fed three groups of superworms different plastic diets — high-density polyethylene, polypropylene and polystyrene — over 30 days. The control group was fed a diet of oatmeal. After feeding the worms plastic, scientists extracted the microbiomes from their gut and incubated them in flasks containing synthetic nutrients and different types of plastics, forming an artificial "worm gut." ❐

Bacteria engineered to produce spider silk in plastic 'microbial upcycling' project

Spider silk protein generates significant development interest due to its unique combination of properties, including high toughness and strength, extensibility, biocompatibility, thermal stability and others. Researchers at Rensselaer Polytechnic Institute (RPI; Troy, N.Y.; www.rpi.edu) have developed what is said to be the first microbial platform to convert hydrocarbons derived from waste polyethylene (PE) into a silk protein similar to spider dragline spidroin, a complex biopolymer that has potential uses in coatings, packaging, fibers and sustainability applications.

"Spider silk is nature's Kevlar," says Helen Zha, an assistant professor of chemical and biological engineering and one of the RPI researchers leading the project. "It can be nearly as strong as steel under tension. However, it's six times less dense than steel, so it's very lightweight. As a bioplastic, it's stretchy, tough, nontoxic and biodegradable."

The RPI team used synthetic biology tools to engineer a new strain of *Pseudomonas aeruginosa* that contains genomically integrated recombinant genes for "spider dragline-inspired silk protein," a biopolymer with the desired properties. The RPI team, collaborating with colleagues at Argonne National Laboratory (Lemont, Ill., www.anl.gov), subsequently demonstrated that the bacteria could convert plastic-derived substrates to protein-based materials. The polymer was "pre-digested" into smaller segments to allow the bacteria to ferment the material.

Non-biological methods for upcycling polyethylene, such as catalytic depolymerization and pyrolysis, are energy intensive and limited in the products they can generate, the researchers explain. The current study points the way to utilizing waste polyethylene to make a highly valuable biomaterial.

The researchers are now working to optimize the recombinant gene in the bacteria to increase efficiency and decrease costs of the system. ■

Business News

Plant Watch

Petrobras to build 'green' hydrogen pilot plant with Senai ISI-ER

February 12, 2024 — Petrobras (Rio de Janeiro, Brazil; www.petrobras.com.br) entered into a cooperation agreement with Instituto Senai de Energias Renováveis to build a pilot electrolysis plant to study 'green' hydrogen production. The facilities of Petrobras' Alto Rodrigues photovoltaic power plant in Rio Grande do Norte, Brazil will be used for the pilot. The project is estimated to take three years and cost BRL90 million (around $18 million).

Plug Power starts up liquid-hydrogen plants in Tennessee and Georgia

February 7, 2024 — Plug Power Inc. (Latham, N.Y.; www.plugpower.com) has re-started operation of its hydrogen plant in Charleston, Tenn., adding about 10 metric tons per day (m.t./d) of liquid-hydrogen production capacity. Plug Power also recently began production of liquid green hydrogen at its new plant in Woodbine, Ga. — the largest plant of its type in the U.S. This plant is designed to produce 15 m.t./d of liquid green hydrogen.

AGC to build new plant for ion-exchange membranes in Japan

February 2, 2024 — AGC, Inc. (Tokyo; www.agcchem.com) will construct a new production facility for fluorinated ion-exchange membranes at its Kitakyushu plant in Japan. AGC will invest approximately ¥15 billion (around $100 million) for the new facility, which is scheduled to start operation in June 2026. Membranes produced at the plant are used in water-electrolysis systems.

Arkema starts up expanded elastomers plant in France

February 1, 2024 — Arkema S.A. (Colombes, France; www.arkema.com) started up its new elastomer unit at the Serquigny plant in France. This new unit can produce both bio-based and traditional grades of elastomers. According to the company, the new site features an improved design that reduces water consumption by around 25%.

Evonik expands production of precipitated silica at Charleston site

January 31, 2024 — Evonik Industries AG (Essen, Germany; www.evonik.com) has invested in a plant expansion for precipitated silica at its site in Charleston, S.C. Construction of the new production line is scheduled to begin in mid-2024. Operations will start in early 2026. With the new line in Charleston, Evonik will increase its production capacity for precipitated silica at the site by 50%. Silica is a key ingredient for tires, toothpaste, coatings and more.

Fujifilm starts up new production site for CMP slurries

January 30, 2024 — Fujifilm Corp. (Tokyo; www.fujifilm.com) announced that its new production facility for chemical-mechanical-polishing (CMP) slurries, a basic material used in semiconductor manufacturing processes, has begun full-scale operation at Fujifilm's Kumamoto production site. CMP slurries are polishers for evenly leveling semiconductor surfaces, which contain a mixture of wires and insulation films of varying hardness. Fujifilm also has CMP slurries production in Arizona and Cheonan, South Korea, as well as in Hsinchu, Taiwan.

Toray commissions upgraded carbon-fiber plant in Alabama

January 30, 2024 — Toray Composite Materials America, Inc., a company of Toray Group (Tokyo, Japan; www.toray.com), has commissioned its upgraded carbon-fiber production line at its Decatur, Ala. facility. The $15-million upgrade doubles the production capacity of carbon fiber. The company has other locations in Tacoma, Wash. and Spartanburg, S.C., producing precursor, carbon-fiber and prepreg materials.

Kraton upgrades biorefinery facility in Panama City, Florida

January 29, 2024 — Kraton Corp. (Houston; www.kraton.com) has completed a $35-million investment to upgrade its crude tall oil (CTO) biorefinery towers in its Panama City, Florida manufacturing facility. This upgrade project is Panama City's largest single capital investment in the last 50 years, says Kraton.

Linde to build new air-separation unit for SAIL in India

January 25, 2024 — Linde plc (Guildford, U.K.; www.linde.com) expanded its existing longterm agreement for the supply of industrial gases with Steel Authority of India Ltd. (SAIL), one of the largest steelmaking companies in India. Under the terms of the new agreement, Linde will build, own and operate an additional 1,000-m.t./d air-separation unit (ASU), nearly doubling Linde's onsite production at SAIL's Rourkela steel plant in Odisha, eastern India. Linde's investment is expected to be approximately $60 million. Expected to come online in 2026, Linde's new facility will also supply industrial gases to Linde's existing and new local merchant customers in the region.

Solvay expands production capacity for hydrogen peroxide in China

Solvay S.A. (Brussels, Belgium; www.solvay.com) is further expanding the production capacity for hydrogen peroxide at its Shandong Huatai Interox Chemical site in China. Building on

LINEUP

AGC
ARKEMA
BASF
CORBION
EVONIK
FUJIFILM
KEMIRA
KRATON
LINDE
PETROBRAS
PLUG POWER
SAINT-GOBAIN
SOLVAY
TORAY

Look for more latest news on chemengonline.com

its existing partnership with Huatai Chemical, the strategic alliance will enable the site to produce 48,000 m.t./yr of photovoltaic-grade hydrogen peroxide by 2025. This strategic investment positions Solvay to meet the rising demand from the photovoltaic industry.

Mergers & Acquisitions

BASF to divest shares in its two joint ventures in Korla, China

February 12, 2024 — BASF SE (Ludwigshafen, Germany; www.basf.com) announced that in late 2023, it started the process to divest its shares in the two joint venture companies BASF Markor Chemical Manufacturing (Xinjiang) Co. and Markor Meiou Chemical (Xinjiang) Co., both located in Korla, China. The divested assets are involved in the production of 1,4-butanediol and polytetrahydrofuran.

Kemira completes the divestment of its Oil & Gas portfolio

February 5, 2024 — Kemira Oyj (Helsinki, Finland; www.kemira.com) completed the divestment of its Oil & Gas business portfolio to Sterling Specialty Chemicals LLC, a U.S. subsidiary of Artek Group, a global industrial chemicals organization based in India. The total consideration on a cash and debt-free basis amounts to approximately $280 million for the acquisition, which includes three of Kemira's manufacturing facilities in the U.S. and the liquid-polymer manufacturing assets in Botlek, the Netherlands.

Saint-Gobain acquires International Cellulose Corp.

February 2, 2024 — Saint-Gobain S.A. (Courbevoie, France; www.saint-gobain.com) has completed the acquisition of International Cellulose Corp. (ICC), a manufacturer of specialty insulation in the U.S., including spray-on thermal, fireproofing and acoustic finish systems. ICC generated revenues of around $30 million in 2023, and operates a manufacturing site in Houston, Tex.

BASF ECMS acquires Arc Metal AB

February 2, 2024 — BASF announced that BASF Environmental Catalyst and Metal Solutions (ECMS) has completed the acquisition of Arc Metal AB in Hofors, Sweden. The asset purchase adds capacity for toll smelting and processing of spent automotive-catalyst materials in Europe, the Middle East and Africa, and further complements ECMS's existing precious-metal recycling operations in Cinderford, U.K., Seneca and Spartanburg, S.C. and Caldwell, Tex. The additional smelting capacity at the Sweden site will also increase utilization of new metals-refinery capacity in Seneca, S.C.

Corbion enters agreement to divest emulsifiers business

January 29, 2024 — Corbion N.V. (Amsterdam, the Netherlands; www.corbion.com) will sell its emulsifier business to private-equity firm Kingswood Capital Management (Los Angeles, Calif.) for $362 million. According to Kingswood, the transaction will create the largest standalone pure-play emulsifiers business in North America. The sale is contingent upon certain conditions, including regulatory approvals. ■

Mary Page Bailey

New Heat Exchangers Improve Performance and Sustainability

Improvements in energy efficiency, reliability and operational boundaries reduce emissions and cut costs

Due to a demand to increase margins and meet sustainability and decarbonization targets, today's chemical processors are seeking ways to improve energy efficiency and reliability while also reducing emissions. Fortunately, innovations in heat exchangers are helping them meet these goals. Recent and anticipated heat-exchanger developments are pushing traditional operational boundaries to increase heat-transfer efficiency and reduce utility consumption and maintenance needs, while also improving operational performance, even in the severe conditions associated with the chemical process industries (CPI).

"Innovations and new developments in heat exchangers are driven by process needs or the need to operate the plant more efficiently — or more importantly — safely," says Rutger Theunissen, chief business officer of services and supplies with Lummus Technology (Houston; www.lummustechnology.com). "We continue to look for ways to improve our heat exchangers to meet a variety of needs: improving sustainability and reducing environmental impacts (such as implementing electrification or lowering emissions from firing); using materials-science innovation to ensure the materials of construction can withstand more severe conditions; and improving fouling mitigation and optimizing maintenance requirements to reduce operating expenses."

Boosting heat-exchanger efficiency

As sustainability goals continue to expand, increasing the efficiency of heat transfer is becoming a growing priority for manufacturers of heat exchangers, and they are rising to the challenge with tweaks on existing technologies and the development of new ones that manage to boost efficiency, operational performance and reliability, allowing chemical processors to cut costs, increase profits and reduce their carbon footprint.

"All chemical processing industries are developing roadmaps and targets for decarbonizing their processes and reducing emissions," notes Alasdair Maciver, who is responsible for the development of business and heat exchanger solutions with the clean-technology space, specifically in energy storage applications, at Alfa Laval (Lund, Sweden; www.alfalaval.com). "The most effective short-term way of doing this is by reducing energy consumption, which means increasing energy efficiency. Plate-type heat exchangers are fundamentally more efficient than tubular types, so this is an obvious low-hanging fruit for them. The more challenging part is to increase the scope of plate heat exchangers, moving plate heat exchangers into larger and more demanding processes in terms of capacity, pressure, temperature and aggressive fluids."

He continues: "We are focusing our heat-exchanger development to make heat exchangers that are even more efficient, reliable and cost competitive from a lifecycle perspective. Specifically, this means working with optimization of the plate design for thermal efficiency, new materials for strength

FIGURE 1. Spirax Sarco's Turflow heat exchangers offer a straight corrugated-tube design that induces turbulence in the flow of the fluid, providing a self-cleaning effect, which reduces scale buildup and delivers a more consistent and higher heat-transfer rate

IN BRIEF

FIGURE 2. Lummus launched a new Polaris breech-lock closure for high-temperature, high-pressure heat exchanger closures used in the hydroprocessing industry. High-pressure exchangers with breech-lock or screw-plug-type closures are used for hydrocracking, hydrotreating, lubricant oil, slurry and residue upgrade processing

and corrosion resistance, increasing pressure and temperature limits, improving ease of service and connected services."

Samuel Glover, Jr., global product manager for plate heat exchangers with SPX Flow (Charlotte, N.C.; www.spxflow.com), adds: "Significant developments continue to take place that are focused on improving heat-transfer efficiency of the heat-exchanger unit. Often, this means working to provide the end user with their required heat transfer in a smaller footprint, both in size and energy consumption, which can result in cost savings.

"A more efficient system also means a more sustainable one," Glover continues. "By helping processors optimize their equipment, in both new builds and existing systems, we can help them reach goals around energy use, as well."

Spirax Sarco Ltd. (Blythewood, S.C.; www.spiraxsarco.com) is also working on innovations that increase not only the efficiency, but the performance of their heat-transfer solutions, says Chris Rossi, product manager for thermal energy solutions with the company. "Because processors are always looking to see how they can continue to make products to their internal standards, while also delivering profit to shareholders and trying to be a more sustainable entity, it's an important goal for us to develop solutions that can deliver."

As such, the company recently updated several heat exchangers, including the Turflow, a high-efficiency heat transfer solution and EasiHeat with dual control. Spirax Sarco's Turflow heat exchangers (Figure 1) are compact in design and suitable for a range of fluids, including steam. The straight, corrugated-tube design induces turbulence in the flow of the fluid, providing a self-cleaning effect, which reduces scale buildup and, therefore, maintenance needs. And, unlike traditional shell-and-tube heat exchangers, it delivers a more consistent and higher heat transfer rate, creating a solution that also improves heat transfer efficiency.

While the Turflow relies on design to increase efficiency, the Spirax EasiHeat implements enhanced control to achieve higher levels of efficiency. EasiHeat is a complete, ready-to-use steam-to-water heat-transfer system that delivers energy efficiency performance in applications with stable load conditions. The dual-control design combines the benefits of both steam and condensate control and provides a high level of set-point accuracy while providing sub-cooled condensate under any operating load changes. The steam-side control allows users to heat only the water that is required and, by reducing steam demand, it helps to reduce CO_2 emissions by using the latent heat from the condensate. The condensate control ensures that all the useful energy in the steam is used within the unit, resulting in less waste, which in turn, reduces both fuel demand and CO_2 emissions.

Performance and reliability

However, as heat-exchanger manufacturers understand that even the most efficient heat exchanger is of no use to chemical processors if it cannot handle the operational extremes of the industry, they are working on adapting solutions to meet the performance demands of chemical processing.

"In addition to efficiency, the current trend we are seeing is a real drive towards increases in operating temperatures and pressures," explains Albert Bedell, technical director with Solex Thermal Science (Calgary, Alta., Canada; www.solexthermal.com). "This seems to be due to an increase in focus on energy recovery and overall efforts to reduce the energy intensity of the process heat. Processors are taking a fresh look at their processes and are taking a 'nothing-is-sacred' approach to reimagining things."

He continues: "The rub here is that a lot of these processes are operating at temperatures well beyond what standard heat exchangers can operate at — say north of 600 or 700°C. The low availability of options in this temperature range is a chal-

FIGURE 3. SPX Flow's new plate heat exchanger FastFrame offers improved usability and durability. The new design includes opening and closing via a powered wrench in under two minutes, consistent tightening across the plate pack and improved safety from the leg/foot design

lenge we hear about quite often."

Bedell says Solex is working on finding options to move beyond the temperature limits imposed by using steels as materials of construction. "One of the big shifts we've made over the past few years is to rethink the overall geometry of our exchangers for these applications, which gives us a lot more flexibility to use different materials," he says. "We are currently moving through the development of some prototypes and are very excited to see how far we'll be able to push the temperature limits of our equipment in 2024."

Also hoping to safely implement heat exchanger technologies at extreme temperatures and pressures, Theunissen says Lummus launched a new Polaris (Figure 2) breech-lock closure for high-temperature, high-pressure heat-exchanger closures used in the hydrocarbon processing industry. The technology incorporates two new features. The ProSeal system, a new gasket loading design, requires no internal split ring, flange or bolts for simplified fabrication, assembly and disassembly. The load to the seal is efficiently distributed and maintained under a wider range of operating conditions. The ProSeal system further protects the components from damage and deformation caused by plant upsets and differential thermal expansion.

And, complementing Polaris's new sealing system is the ProLock closure system, a securing mechanism using a special appliance that is simpler and safer to operate. The design allows easy access to all threads for maintenance, lubrication and repair and significantly reduces the time needed for inserting and removing the closing plug.

High-pressure exchangers with breech-lock- or screw-plug-type closures are used in the hydroprocessing industry, primarily for hydrocracking, hydrotreating, lubricating oil, slurry and residue-upgrade processing. Applications include use in reactor feeds and effluent exchangers, recycle gas exchangers, effluent recovery and gas recovery exchangers and other applications in gas compression and fertilizer processes.

SPX also recognized the importance of boosting the performance and reliability of heat-transfer systems and has developed a technology that makes it easier and less time consuming to maintain heat exchangers, helping to reduce operating expenses. The company's new plate heat exchanger FastFrame (Figure 3) offers improved usability and durability. The new design includes opening and closing via a powered wrench in under two minutes, consistent tightening across the plate pack and improved safety from the leg/foot design. "Using the traditional method, processors spend significant amounts of time and lose valuable production hours cleaning heat exchangers," says SPX's Glover. "This frame design speeds up the process, taking only minutes."

New applications

Not only do improvements in heat-transfer efficiency, performance and reliability optimize energy usage, reduce a facility's carbon footprint and improve the overall performance and efficiency of the plant, but today's more efficient and effective heat exchangers are opening the door to interesting new applications — many of which are helping the world itself become a more sustainable place.

For example, Lummus recently announced a partnership with NET Power Inc. (Raleigh, N.C.; netpower.com) to supply recuperative heat exchangers for near-zero-emissions power generation. "We recognize the design and supply of heat-exchanger systems into supercritical CO_2 power-generation cycles where efficiency and the ability to withstand high pressures (400 bars) and high temperatures (600°C) as an important move for the industry. This is a challenging application, but at the same time extremely interesting and valuable," says Lummus's Theunissen. "It is an application that will help operators and their power plants deliver clean, reliable and low-cost energy."

And, according to Alfa Laval's Maciver, there is also "enormous potential" around hydrogen and car-

Alfa Laval

FIGURE 4. Alfa Laval's HyBloc Printed Circuit heat exchanger was designed for hydrogen precooling in filling stations. It is small, modular, scalable and designed to fit into existing pump delivery systems and supports the high operating pressures necessary to shorten the time it takes to fill a vehicle's tank

bon-capture applications. "Hydrogen is such a broad scope, from electrolyzers and fuel-cell components, refueling stations for hydrogen-fueled vehicles, compression stations and other parts of the hydrogen production and distribution infrastructure." To help support hydrogen efforts, Alfa Laval recently developed its HyBloc Printed Circuit heat exchanger (Figure 4), which was designed for hydrogen precooling in filling stations. HyBloc is small, modular, scalable and designed to fit into existing pump delivery systems. It supports the high operating pressures necessary to shorten the time it takes to fill a vehicle's tank. The technology also offers a high capacity in the precooler, which reduces wait time between fillings. Durable, fusion-bonded plates make the units robust and allow them to withstand pressures up to 1,250 bars and operating temperatures as low as –70°C.

Also in the realm of carbon capture and hydrogen, Tranter (Solna, Sweden; www.tranter.com) is supplying plate-and-frame heat exchangers constructed of stainless steel and 254 SMO with ethylene-propylene-diene-monomer (EPDM) rubber gaskets to a carbon-capture application in a new "blue" hydrogen plant in Texas. Tranter's heat exchangers with ThermoFit plates in the Omniflex plate pattern will be used as vent condensers and for heat recovery between the lean and rich solvent, where the rich solvent has absorbed the CO_2 from a gas stream and needs to be heated prior to entering the desorption column where the CO_2 is separated from the solvent, making it lean. The lean solvent in turn needs to be cooled down before being reintroduced into the absorber. The plate-and-frame heat exchangers used for vent condenser will condense any evaporated solvent in the desorption step back into the column.

And, as heat exchanger manufacturers continue to realize the importance of efficient, robust exchanger options for sustainability-based applications, we can expect to see more innovations in the next few years.

For example, Solex's Bedell suggests that there is a tremendous amount of interest in the cement industry in reducing its overall carbon intensity through energy recovery from solids. "When you look at the size of the cement industry, even marginal improvements can have a big impact on global carbon emissions and some of the improvements being developed are more revolutionary than marginal," he says. Another area where he sees a growing interest is using solids as part of the carbon-capture process, and developments in heat-exchanger technologies will allow them to play a starring role in this application. "For both the carbon-capture and cement applications, there don't seem to be great off-the-shelf options for moving-bed heat exchangers, so this is really going to be an interesting area to watch for new innovations and developments in the next few years."

Another company, Makai Ocean Engineering (Waimanalo; Hawaii; www.makai.com) is partnering with Shell Technology's Marine Renewable Program to develop and test potentially transformative propriety technologies that may advance the engineering and economic viability of an offshore Ocean Thermal Energy Conversion (OTEC) system. Makai's concepts for OTEC systems and a "cutting-edge" thin-foil heat exchanger technology hold the potential to reduce the capital and operating costs of an offshore OTEC system. The partnership and research are intended to explore how to achieve more value with lower emissions through ocean-based renewable energy systems and an advanced heat exchange solution may be the key.

It appears that as chemical processors, power generators and other heavy industries continue to drive toward more efficient and sustainable operations and applications, heat-exchanger developers will strive to create and deliver the necessary heat-transfer technologies to meet these growing needs, helping processors meet sustainability and operational goals along the way. ■

Joy LePree

Pipes, Tubes and Fittings

This pipe-fitting line has been expanded

This company recently expanded its line of carbon-steel fittings (photo) to bring more press options for plumbing and mechanical carbon-steel pipe applications, as well as fuel and gas carbon-steel pipe applications. The BenchPress and BenchPressG fittings are designed for efficiency, with easy, clean and fast installation, for a wider range of applications. The line features a patented fitting design that creates consistent joints, is flame-free and environmentally friendly. These heavy-duty fittings feature stainless-steel grip rings and separator rings. Available in 0.5- to 2-in. sizes, the BenchPress and BenchPressG fittings can be installed within seconds and require no threading equipment and lubricants, while maintaining joint integrity and professional appearance. — *Nibco Inc., Elkhart, Ind.*
www.nibco.com

One person can handle this pipe-beveling tool

The Mini-Millhog (photo) is a portable pneumatic-clamping tube and pipe beveling tool for machining of tube and pipe from 1.25 in. I.D. to 6.625 in. O.D. The tool is self-centering with one mandrel covering the majority of the range. With a working weight of 27.5 lb, this high-torque tool is easy to handle and provides smooth chatter-free operation on highly alloyed stainless steel and heavy wall pipe without using cutting fluids. Capable of producing any angle of preparation, the Mini-Millhog is a robust tool with all clamping components used to rigidly secure the tool on the I.D. of the tube or pipe. Also available with an electric motor, this versatile tool can remove tube-weld overlay and membrane cladding in boiler systems. — *ESCO Tool, A Unit of ESCO Technologies, Inc., Holliston, Mass.*
www.escotool.com

Compact separator has a stainless-steel housing

This company has launched a new pipe magnet (photo) that requires half the installation height of its predecessor and is also twice as strong. Manufactured entirely from stainless steel, the magnetic separator contains a core of neodymium (NdFeB) magnets and creates a flux density of 12,000 Gauss. The conical-shaped magnet core contains more pole plates, so even 30-µm particles stick to more engagement points, resulting in a higher degree of separation. Steel particles present in the product flow, such as bolts, nuts, washers, screws, small metal balls, broken threads and clips can be separated from grains, flour and other incoming goods flows. The new magnet system is suitable not only for mounting in free-fall pipes, but also for pressure pipes. — *Goudsmit Magnetic Systems B.V., Waalre, the Netherlands*
www.goudsmitmagnets.com

Remove ferrous impurities from free-flowing materials

The Magnetic Separator (photo) removes ferrous impurities quickly and easily from free-flowing bulk materials and exhaust air with low delivery pressure. It has a compact and sturdy construction composed of several rod magnets in a protective stainless-steel casing. Depending on the diameter, up to nine neodymium rod magnets remove even the smallest ferrous particles from bulk materials and exhaust air. This magnetic separator can be used in all industries that require removal of ferrous metals from the product flow. For example, it can be used for the protection of downstream machines, such as in plant engineering or the plastics industry, or for the safe production of food products, such as flour or sugar. The separator is available with diameters of 100, 150, 200, 250 and 300 mm. — *Fr. Jacob Söhne GmbH & Co. KG, Porta Westfalica, Germany*
www.jacob-group.com

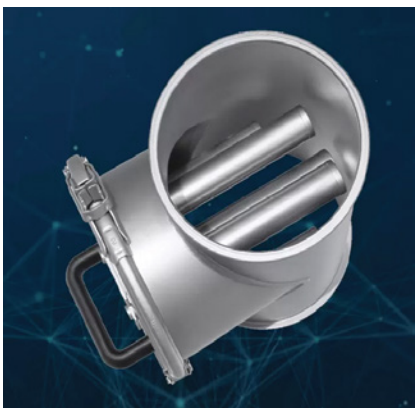
Handheld videoscope supports inspection tasks

The TVGM Series is a family of miniature, high-definition handheld industrial-grade videoscopes (photo, p. 18) designed to support a variety of non-destructive testing and remote

Nibco

ESCO Tool, A Unit of ESCO Technologies

Goudsmit Magnetic Systems



Fr. Jacob Söhne

Titan Tool Supply

Flangeguards

SignalFire Wireless Telemetry

Swagelok

visual inspection tasks. Offered in four models, with a choice of either a 3.9- or 6-mm camera and either a 1.5- or 3-m videoscope probe length, the TVGM Series features dual-key operation, a fully modular and ergonomic design and end-user capability to easily swap out probe lengths for increased application adaptability. At the heart of each videoscope is a powerful onboard controller delivering high-definition imaging, reliability and stability. Typical applications include remote visual inspections of smaller-sized precision industrial machinery and equipment, as well as hydraulic and pneumatic parts, steel pipes, castings and containers, even in low- or reduced-light conditions and space-constrained environments. — *Titan Tool Supply Inc., Buffalo, N.Y.*
www.titantoolsupply.com

Prevent flange-joint spray-out with this shield

Pipe safety shields are used to prevent the harmful spray-outs and mist formation of dangerous liquids or steam from failing pipe joints. Sureband Steel (photo) can be applied to a flange in 5 seconds by simply wrapping the shield around the flange and clipping to the appropriate size. The flexible sizing feature of Sureband means one shield can fit many different flange sizes. Where bag-type shields collect and store dangerous liquids, Sureband Steel offers an optional drain component. In the event of a breach of the flange joint, Sureband employs unique pressure-diffusion technology to channel hazardous liquids into a convenient and safe drip, which can be dealt with simply using the drain. — *Flangeguards Ltd., Basildon, Essex, U.K.*
www.flangeguards.com

Remote monitoring system for pipeline integrity

This company is partnering with Axess-Corrosion, a U.K. provider of corrosion monitoring sensors, in integrating its Ranger cellular transmitter in a new pipeline-corrosion monitoring system. The new pipeline-corrosion monitoring system from Axess-Corrosion (photo) combines the Ranger internet of things (IoT) transmitter with a sacrificial sensing probe to provide data and alarms on pipeline corrosion levels. In operation, the probe, which is inserted into the pipe, is equipped with a depleting "sacrificial" membrane and can detect corrosion or erosion of the membrane as finite as 0.0001 in. By measuring depletion rate, the probe provides feedback on the predicted rate of corrosion on the pipeline wall. Utilizing the latest cellular LTE CAT M1 with MQTT/SparkPlugB technology for remote locations, the battery-powered Ranger cellular transmitter powers the corrosion sensors, then gathers and transmits data from the sacrificial probe to the cloud for remote monitoring control, and alarm from any web browser including mobile devices. By publishing over cellular networks using MQTT and TLS security, the Ranger IoT cellular transmitter is isolated from local area networks to offer a more secure connection, the company says. — *SignalFire Wireless Telemetry, Marlborough, Mass.*
www.signal-fire.com

These two-ferrule fittings save time and money

Stakeholders in charge of medium- and high-pressure fluid-system applications for hydrogen fuel-cell technologies and downhole oil-and-gas exploration can achieve significant time and labor savings by switching from traditional cone-and-thread fittings to FK series two-ferrule tube fittings (photo). Using FK series fittings, assemblers have been able to complete fitting installations approximately five times faster, while virtually eliminating rework needed during hydrotesting and acceptance test steps, the company says. In service, FK series two-ferrule tube fittings help to improve system reliability and reduce overall maintenance needs. These efficiencies deliver significant savings and a reduced total cost of ownership. FK series fittings feature a female fitting body and a pre-assembled cartridge containing the male nut and color-coded front and back ferrules on a disposable arbor. The preassembled cartridge ensures correct ferrule orientation, visual confirmation of ferrule presence, and proper installation into the female body. The fittings are available in 316 stainless steel, alloy 2507 and alloy 625. — *Swagelok Company, Solon, Ohio*
www.swagelok.com

Gerald Ondrey

New Products

New controller brings simplicity and flexibility to single loops

The Fisher Fieldview DPC2K digital process controller (DPC2K: photo) can be retrofitted to Fisher Wizard pneumatic controllers, and to pneumatic controllers from other manufacturers. Closed-loop control is greatly improved with configurable loop types, over 150 units of supported measure, 20 times-per-second (50 ms) scan and update rates, configurable dead band and other features. These features work together to keep the process variable — typically pressure, flow, level or temperature — close to setpoint, along with greatly improved recovery from saturated conditions. The DPC2K can accept a 4–20-mA input from a two- or four-wire instrument, typically the process variable. — *Emerson, Marshalltown, Iowa*
www.emerson.com

Emerson

Big-bag discharge station with dust-free docking station

The Big-Bag Unloader (BBU; photo) features a new, dust-free docking station. Included as standard equipment on the bulk-bag unloader, the new docking station features a proprietary design with integrated inner ring, outlet spout and cover that establish a sealed connection between the bag and the discharge. Material transfer from bulk bags into a hopper, reactor, pneumatic conveyor or another location moves freely for fast, safe, complete emptying without clogging while any dust is neatly contained within the docking station. The docking station is offered in a wide range of sizes to match the bag and material properties to the discharge spout. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

Gericke USA

Bag-dump station with optional dust collector

The RNT line of bag-dump stations (photo) features an integrated dust-collection system as an option. Devised to prevent nuisance dust exposure in the work environment, the dust-control equipment sets a vacuum pump and filter system atop the bag-dump station to automatically capture any fine particles generated during bag emptying and safely contain them within the process. The system automatically starts up when the dust hood and door are opened during bag discharge and automatically back-pulses the filter when closed to release the material into the process. The integrated dust-control bag-dumping stations provide a fully enclosed material-transfer process that helps control ignitable powders and combustible dust. — *Volkmann, Inc., Bristol, Pa.*
www.volkmannusa.com

Volkmann

A system to clean ducts and tanks in hygienic processing lines

The new Free Rotating Retractor (photo) is a high-efficiency retractable cleaning device that quickly and effectively removes residues from the interior surfaces of hard-to-clean vessels. This retractable cleaning-in-place (CIP) device remains sealed off from the product area during production, flush with the vessel wall. The spray head slides out, expelling cleaning media in a 310-deg, upward spray pattern across the vessel surface. Upon completion of the cleaning cycle, the spray head retracts, and the vessel is production-ready. The cleaning device delivers up to 35% savings in water, chemicals and time for every CIP cycle compared to conventional static spray-ball technology, the company says. — *Alfa Laval AB, Lund, Sweden*
www.alfalaval.com

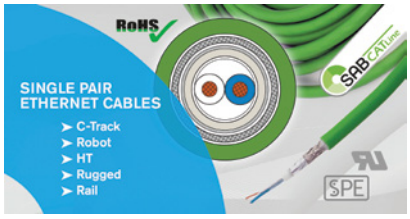
Alfa Laval

Versatile, high-performance gas detection with easy deployment

The iTrans 2 fixed gas detector (photo) provides one or two points of detection from a single head for maximum flexibility, with both readings shown on the standard-issue LED and display. Gas sensors are mountable directly to the transmitter, or remotely. For the detection of explosive and toxic gas, or oxygen, the iTrans 2 accepts infrared (IR), catalytic bead or electrochemical sensors. Specifically, in addition to the LEL (lower explosive limit) sensor range, the iTrans 2 is configurable with a 0–100 vol.% methane IR sensor for biogas applications and CO_2 infrared sensors ranging from 0.5 to 100 vol.%. — *Teledyne Oldham Simtronics SAS, Arras, France*
www.teledynegfd.com

Teledyne Oldham Simtronics

AGI Glassplant



SAB Brockskes

Lauda DR. R. Wobser

Renewable Lubricants

Force Control Industries

A controller for pilot-scale reactor automation

The Pilot Reactor Controller (photo) provides easy control, automation and monitoring of any pilot reactor and associated devices via a single software interface. Designed for the pharmaceutical, chemical, contract-research or manufacturing organization (CRO/CMO), agrochemical and flavor and fragrance sectors, this modular and scalable system provides easy integration of third-party devices, offering secure and robust data connections. The controller is an easy-to-use, turnkey system suitable for chemists and chemical engineers looking to scale up from laboratory to pilot plant or, conversely, down from production to pilot scale. Using OPC Unified Architecture, this next-generation reactor controller offers universal connectivity with a vast range of reactors and peripheral devices (including circulators, stirrers, sensors and pumps) via a no-code software interface. — *AGI Glassplant Inc., Takahama, Arao-City, Japan*
https://go.agi-glassplant.com

New cables introduced for automation and more

Extending its CATLine product series (photo), this company has launched application-tailored single-pair Ethernet (SPE) cables in five variants. Compared to conventional four-pair Ethernet connections, SPE offers significant savings potential in material, space and costs as high data rates can be transmitted over long distances with just one pair of copper cores. The newly developed CATLine SPE cables can withstand high mechanical loads and temperatures and are highly resistant to chemicals, oils and cleaning agents. — *SAB Bröckskes GmbH & Co. KG, Viersen, Germany*
www.sab-cable.com

This ultralow-temperature chest is battery powered and mobile

The Mobifreeze M 270 (photo) is said to be the first mobile battery-powered ultralow-temperature chest freezer. Valuable samples or active pharmaceutical ingredients (APIs) can be safely stored and transported from –86 to –50°C. Natural refrigerants are used to provide active temperature control instead of dry ice. The chest freezer has a battery life of 4 h and therefore enables the cold chain to be reliably maintained in intralogistics and for inter-factory transport in road logistics. Cooling is freely adjustable between –86 and –50°C. If the set limits are exceeded, a warning is provided by an acoustic and visual signal. An integrated data logger stores the temperature and alarm data. The freezer is operated via a 4.3-in. touchscreen, whose functionality is also not restricted by gloves. Password-protected user management prevents unauthorized access to configuration parameters. — *Lauda Dr. R. Wobser GmbH & Co. KG, Lauda-Königshofen, Germany*
www.lauda.de

Bio-based oils handle a wide temperature range

Bio-Process Oils (photo) is a new family of blended, highly-refined biosynthetic base oils that maintain flexibility over a wider temperature range than petroleum-based products, making them suitable for use in many types of adhesives and sealants. Their extremely low volatility increases the flash- and fire-safety features, and there are no volatile organic compounds (VOCs). They are available in viscosity grades (SUS) of 50, 70, 100, 150, and 200, to suit a wide range of applications, climates and preferences. Stabilized to resist oxidation and provide light color stability, they are odorless and chlorine-, and sulfur-free. The oils are high in oleic-acid content for higher stability over conventional vegetable oils. — *Renewable Lubricants, Inc., Hartville, Ohio*
www.renewablelube.com

Clutch breaks for inclined conveyor applications

Posidyne X-Class clutch brakes (photo) are suitable for incline conveyor applications because they provide precise positioning each cycle. They act as a holding brake so that materials never slide backward on the incline. The clutch brakes feature Oil Shear Technology, which provides a film of transmission fluid between the brake disc and the drive plate. As the fluid is compressed, the fluid molecules in shear transmit torque to the other side. This torque transmission causes the two components to reach

the same relative speed. Since most of the work is done by the fluid particles in shear, wear is virtually eliminated. These brakes last up to 10 times longer than standard dry friction brakes and do not need maintenance, adjustment, or disc replacement. — *Force Control Industries, Inc., Fairfield, Ohio*
www.forcecontrol.com

This chiller does not use refrigerants

This company is now offering its first refrigerant-free chiller. The TE400 (photo) utilizes Peltier technology to provide efficient laboratory cooling with a range of –5 to 40°C and a cooling capacity of up to 400 W. It is equipped with a pump capacity of 7 L/min with pressure to 17.4 psi. The benchtop TE400 is suitable for temperature control with circulation to an external application. In addition to its environmentally friendly footprint, the TE400 is easy to operate and requires minimal low maintenance. With fewer wearable components than a refrigerator (such as a compressor), the TE400 guarantees less downtime. With an additional operating mode labeled Silent Mode, applications with lower cooling requirements can run on a significantly reduced noise level for a more desirable work environment. — *Julabo USA, Allentown, Pa.*
http://julabo.us

This multi-shaft mixer handles viscous formulations

Capable of processing viscous solutions, dispersions, suspensions and emulsions with viscosities in the hundreds of thousands of centipoise, this company's line of VersaMix multi-shaft mixers is built for longevity, speed and efficiency. The VMC-100 (photo), is designed for vacuum operation up to 29.5 in. Hg and supplied with interchangeable 100-gal mix cans, each fabricated with a 50-psig ASME-code stamped jacket for heating or cooling via glycol. The custom electro-hydraulic system is engineered to fully raise the motor drive in 15 seconds. The VMC-100 features three independently driven agitators. A three-wing anchor agitator equipped with optional hinged sidewall and bottom Teflon scrapers improves heat transfer across the jacketed vessel. The high-shear mixer is capable of introducing powders sub-surface while the batch is low in viscosity. — *Charles Ross & Son Company, Hauppauge, N.Y.*
www.mixers.com

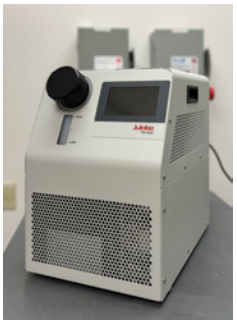
This TDL spectrometer performs accurate O_2 measurements

The TDLS8220 extractive tunable diode laser spectrometer (photo) is a new generation OpreX analyzer. The TDLS8220 laser module and detector module are now encompassed in one board set, but still retain a reference cell for improved reliability of absorption peak detection. In addition, the automatic gain function optimizes detection sensitivity during dynamic process events. Due to the non-contact measurement, sample-handling system upsets or failures will not damage the analyzer sensor. The unique flow-cell design features a tube-in-shell construction that allows tight temperature control of extractive samples at the desired set-point. The analyzer does not require consumables, and solid-state technology eliminates the need for routine calibration. — *Yokogawa Corp. of America, Newnan, Ga.*
www.yokogawa.com/us

This twin-screw feeder delivers precise batch size and weight

The Model TSF twin-screw feeder (photo) is designed for precise batching and weighing applications. The feeder's dual-helix design combines fast, high-volume filling with accurate dribble flow at the end of the cycle. Its compact design is ideal when limited space prohibits multiple individual screw units. Two helices (1.5- and 4-in. dia.) are mounted on an 18 in. × 22 in. hopper. They are rated at 17 and 283 ft^3/h, respectively, at maximum rotational speed with 100%-efficient conveyable product and no slippage. The TSF is suitable for batching to weight hoppers; low loss-in-weight scale-monitored flow; low loss-of-weight batch applications with scales; drum and pail packout lines; and recipe-type batching by multiple computer-controlled units. — *Best Process Solutions, Inc., Brunswick, Ohio*
www.bpsvibes.com

Gerald Ondrey



Julabo USA

Charles Ross & Son Company

Yokogawa Corp. of America

Best Process Solutions

NOx Formation in Combustion

Department Editor: Scott Jenkins

Oxides of nitrogen (NOx) are a family of highly reactive gases that can be produced naturally, but largely result from fuel combustion (industrial combustion and automobile engines). In the environment, they are pollutants that react with volatile organic compounds in complex ways to produce ground-level ozone, and they also play a role in producing smog and acid rain.

NOx formation occurs via different mechanisms: thermal NOx is based on temperature and makes up most of the NOx formed during combustion; fuel-bound NOx comes from nitrogen atoms contained fuels; and prompt NOx is formed when molecular nitrogen in the air combines with the fuel in fuel-rich conditions. This one-page reference outlines these mechanisms largely responsible for NOx formation in industrial combustion

Thermally formed NOx

Thermal NOx is formed by oxidation of N_2 in air and requires sufficient temperature and time to produce NOx. For fuels that contain no nitrogen in the parent molecules (for example, natural gas), this mechanism, also known as the Zeldovich mechanism, produces most of the NOx. This may be approximated by the following integrated rate expression:

$$[\mathrm{NOx}] = A[\mathrm{N_2}]\int_0^t e^{-\frac{b}{T}}[\mathrm{O_2}]d\theta \quad (1)$$

where the brackets indicate the volume concentration of the enclosed species, *A* and *b* are constants, *t* is the total reaction time (with θ serving as the dummy variable in the integration), and *T* is the absolute temperature. So NOx from this mechanism depends on three primary quantities — temperature, oxygen concentration and reaction time — and minimizing any or all of them will reduce NOx. Since temperature is exponentially weighted, the peak flame temperature has an oversized role in NOx formation.

A rule of thumb is that below approximately 1,700K, the residence time in typical gas turbine combustors is not long enough to produce significant thermal NOx. Where temperatures higher than 1,700K cannot be avoided, it is necessary to limit residence time to control NOx formation, which favors very short combustor designs.

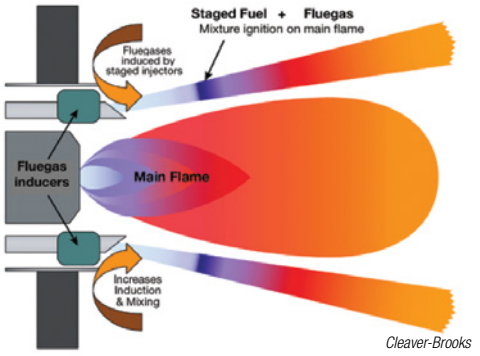


FIGURE 1. Burners with fuel staging inhibit NOx production

Fuel-bound mechanism

If a significant number of fuel molecules contain nitrogen bound in their structure, the overwhelming share of NOx will be formed from the fuel-bound mechanism, leading to a rate equation as shown in Equation (2):

$$[\mathrm{NO_x}] = \kappa\int_0^t [\mathrm{C_xH_yN}][\mathrm{O_2}]d\theta \quad (2)$$

where κ is a constant. Since the reaction is fast, and the fuel concentration is limited by the required stoichiometry, fuel-bound NOx formation may be reduced only by reducing the excess oxygen or switching to lower-nitrogen fuels.

Prompt NOx

The third NOx-formation mechanism is the Fenimore mechanism, also called prompt NOx. It is similar to the fuel-bound mechanism, except that the nitrogen comes directly from the combustion air. Since nitrogen radicals are exceptionally difficult to pare from molecular nitrogen, prompt NOx from this mechanism is usually negligible.

Reducing NOx in burners

Three burner configuration methods exist for reducing nitrogen oxides in burners: staged air, staged fuel and internal fluegas recirculation combined with staged air or staged fuel.

Staged-air burners. These types of burners work by introducing 100% of the fuel into the burner and only part of the combustion air (primary air), thus creating a sub-stoichiometric flame. This flame has a reduced temperature and therefore inhibits NOx formation. The flame is completed with the addition of the secondary air to complete the combustion process. This process allows for greater control at lower burner loads and also accommodates a wider range of fuels.

Staged-fuel burners. This burner method introduces 100% of the combustion air into the burner and splits the fuel supply into primary and secondary volumes. The primary fuel mixes with the combustion air to create a flame (Figure 1). As with staged-air burners, peak flame temperature is lower, and NOx formation is reduced. Secondary fuel is added to complete the combustion process. Staged-fuel burners provide greater NOx reduction, as the fuel supply has a larger effect on NOx formation. This method is more commonly used when a consistent fuel supply is available.

Internal fluegas-recirculation burners. This method combines either staged air or staged fuel with internal fluegas recirculation to help reduce NOx formation. The best results are obtained where internal fluegas recirculation is used to dilute the fuel gas in a staged-fuel burner, creating a gas with a low calorific value. ■

References

1. Stoeger, J., Burner Technologies and Concepts: Meeting Emissions-Reduction Goals, *Chem. Eng.*, Sept. 2022, pp. 34–39.
2. Vij, A.D., Enclosed Combustion Equipment and Technology, *Chem. Eng.*, January 2018, pp. 46–49.
3. Al-Hajji, M.H., Burner Inspection and Maintenance, *Chem. Eng.*, November 2014, pp. 40–45.
4. Colannino, J., Low-Cost Techniques for NOx Reduction, *Chem. Eng.*, May 2020, pp. 30–36.
5. Richards, G., Weiland, N. and Strakey, P., Combustion Strategies for Syngas and High-Hydrogen Fuel, in "Gas Turbine Handbook," National Energy Technology Laboratory (NETL), 2006.

Calibration of Weighing Instruments

A guide to the practical considerations of calibrating weighing instruments is presented here

Ned Espy and Roy Tomalino
Beamex, Inc.

IN BRIEF

Throughout the chemical process industries (CPI), weighing instruments find a range of important uses and are often a critical piece of equipment for many processes. Monitoring feed rates of raw materials by weight, ensuring that exact amounts of chemicals enter final product formulations, dispensing materials for packaging and conducting research and development work all depend on accurate and consistent weighing of materials. Weighing instruments with high accuracy are positively associated with good product quality control, through meeting industry standards; reduced downtime, by maintaining continuous operations; and good environmental compliance, through avoidance of overfilling and spills.

Various types of scales and balances are used for a range of operations across the CPI, including the following: analytical balances for extremely precise measurement; precision balances for weighing chemicals with tight tolerances; industrial scales for heavy loads in bulk chemical production; and hazardous area scales in potentially explosive environnments (Figure 1).

To maintain accuracy and ensure valid measurement results, weighing instruments should be calibrated regularly. A proper, metrologically traceable calibration is the only way to know how accurately weighing instruments are measuring. Some weighing instruments are used for legal measurements or measurements used as basis for monetary transfer. These are part of a legal or statutory verification program based on legislation. Often the calibration of weighing instruments is based on a quality system, such as ISO 9000 (standards for quality assurance in manufacturing; Internantional Organization for Standardization; Geneva, Switzerland; www.iso.org). There are dedicated regulations for weighing instruments and their calibration [*1–3*]. In this article, the main focus is on the practical considerations and required tests for calibrating weighing instruments.

FIGURE 1. Different types of weighing instruments are used in various ways across the CPI

Preparations before calibration

Proper calibration of weighing instruments requires some information gathering and special preparations before beginning, including assembling information about the technical characteristics of the weighing instrument — such as maximum weight, *d* value (ratio of scale capacity to increment size) and so on — as well as the accuracy requirements for the measurement (maximum error allowed and uncertainty). Also, those calibrating weighing instruments need a plan for adjusting the scale, if necessary.

Typically, the entire measurement range of the instrument is calibrated during a calibration session and the calibration should be performed in the same location where the instrument will be used. Before beginning, ensure that there are sufficient calibration weights availiable for the calibration procedure.

The weighing instrument should be switched on at least 30 minutes before starting the calibration. The temperature of the calibration weights should be stabilized to the same temperature as the area where the instrument is located.

The weighing instrument should be level horizontally. This is especially true for small weighing instruments designed for high accuracy. Before starting calibration tests, perform a few pre-tests by placing weights close to the maximum of the measurement range onto the instrument to confirm that it

Beamex

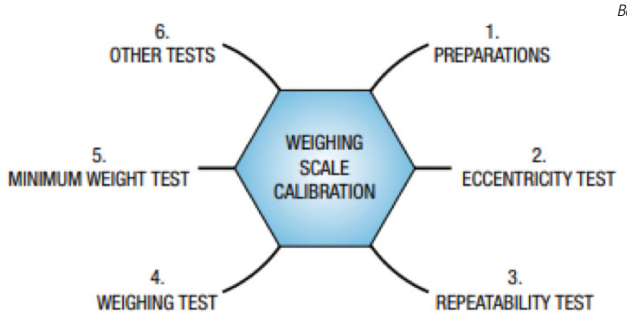


FIGURE 2. Multiple calibration tests, including eccentricity and repeatability, are performed for comprehensive calibration

Shutterstock

FIGURE 4. Calibration repeatability tests measure the variation in results when the same load is weighed multiple times

working normally.

In case the weighing instrument fails in calibration and it is adjusted, you should make an "as found" calibration before adjustment and an "as left" calibration after adjustment.

Calibration tests

The following section outlines the different tests that should be undertaken as part of the weighing-instrument calibration (Figure 2).

Eccentricity test. During normal use of a weighing instrument, loads being weighed are not always located perfectly on the center of the load receptor. Sometimes the results of a weighing instrument can vary slightly depending on the exact placement of the load on the load receptor. In order to determine the extent of the effect that the location of the load has on the measurement results, the eccentricity test is performed.

In an eccentricity test, the reference load is placed in a few different specified locations on the surface of the load receptor. First, the load is placed in the center of the load receptor (the load's center of gravity) and the weighing result is observed. Next, the load is placed in four different sectors of the load receptor offset from the center.

The diagrams in Figure 3 show rectangular and round load receptors, but in practice, there may be many different shapes of load receptors, so the locations of the load can vary. Guidelines for load placement using alternatively shaped load receptors can be found in Standards OIML R76 and EN 45501 [*3, 4*].

The calibration procedure should specify where to place the load during the test and the calibration results (in certificate format) should document the locations where the loads were placed.

The test load used in an eccentricity test should be at least one third of the maximum load for the weighing instrument. If possible, an eccentricity test should preferably be carried out using a single test load for all the measurements. That way, it is easier to be sure that the load's center of gravity is in the specified location. For a weighing instrument with multiple ranges, the eccentricity test should be done at the highest range.

Because the aim of the eccentricity test is to quantify the difference in measurement results caused by differing locations of the load, it is not necessary to use an accurately calibrated test load. However, it is important to use the same load throughout the eccentricity test. If the eccentricity test is also used to determine the errors of the measurements, then a calibrated load should be used.

The procedure for the eccentricity test is as follows: The indication is zeroed before the test. The test load is placed at location 1 of Figure 3 and the indication is recorded. The test load is then moved to locations 2 through 5, and the indication is recorded for each location. Finally, the test load is returned to location 1 again to check that the result has not drifted from the earlier measurement taken at location 1.

The zero may be checked between measurements at each location to see that it has not changed. If necessary, the instrument can be zeroed in between each test. Alternatively, the instrument could be tared when the load is placed at location number 1. This may make it easier to observe any differences between locations.

Repeatability test. Like almost any instrument, weighing instruments may suffer from repeatability issues, which refer to variations in measurement results when the same load is measured multiple times. To assess the repeatability performance of a weighing instrument, a repeatability test is conducted (Figure 4).

A repeatability test is performed by measuring the same load at the same place on load receptor (to avoid any possible eccentricity error) multiple times. Repeatability tests should be carried out under identical and constant conditions and with identical handling protocol.

The load used for repeatability calibration should be close to the maximum load of the instrument. Often a repeatability test is done with one load only, but it can be done also with several different load val-

Beamex

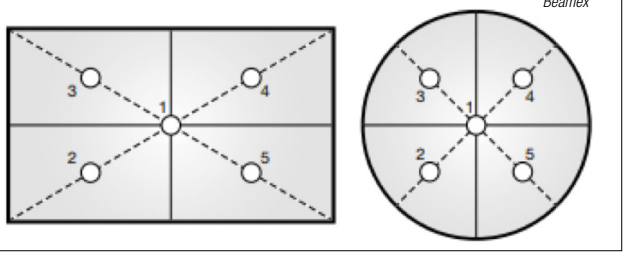


FIGURE 3. The locations of the load for calibration measurements in an eccentricity test are shown for a circular and rectangular load receptors

ues separately. The load does not necessarily need to be a calibrated load, because the aim of the test is to determine the repeatability of the measurements. If possible, the load used for the test should be a single load, rather than several small loads.

A repeatability test is normally done by repeating a measurement at least five times in a row. For instruments with a high range (over 100 kg), at least three measurements should be taken.

In the repeatability test, the instrument is first zeroed, then the load is placed on the load receptor and the indication is recorded once the instrument stabilizes. Then the load is removed and zero indication is checked. Zero the unit again, if necessary. Then the load is placed again, and so on.

For a multi-range instrument, a load that is close to, but still below, the maximum of the first range is often sufficient.

Weighing test. The purpose of the weighing test is to check the accuracy (calibrate) of the weighing instrument throughout its whole range in several steps, with increasing and decreasing weight.

The most common for a weighing practice is the following: start by zeroing the instrument without any load. Set the loads of the first test point, wait for stabilization, then record the indication. Continue increasing the loads through all the increasing test points. Once the maximum load is recorded, start decreasing the loads through the decreasing test points. In some cases, the weighing instrument may be calibrated with increasing loads only or decreasing loads only.

Typically, five to 10 different loads (test points) are used for this test. The heaviest load should be close to the maximum capacity of the instrument. The smallest test load can be 10% of the maximum load, or the smallest weight normally used. Generally, the test points are selected so that they are equally distributed throughout the range. More test points can be used within the typical usage range for the instrument. For multi-range instruments, each measurement range needs to be calibrated separately.

Linearity

In a weighing test, using multiple points throughout the measurement range of the instrument helps to reveal issues with linearity. Linearity issues refer to those indicating that the instrument does not measure with equal accuracy throughout the measurement range. Even if the weighing results for zero and the full span are correct, there may be errors, termed linearity errors, in the middle part of the range.

Figure 5 represents a general illustration of nonlinearity. The instrument's zero and full range are adjusted correctly, but there is error in the midrange due to nonlinearity of the instrument.

Hysteresis is the difference in the measurement result when a test point is approached with increasing

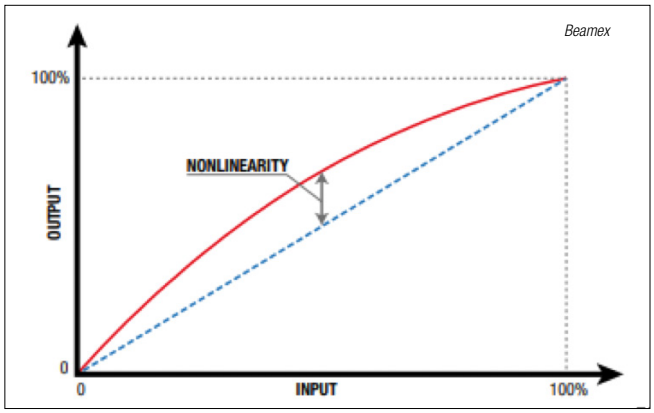


FIGURE 5. Nonlinearity shows that an instrument does not measure with equal accuracy across the entire measurement range

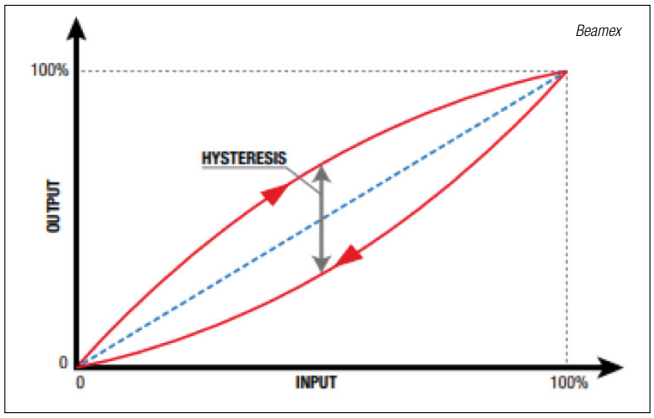


FIGURE 6. Hysteresis refers to differences in measurement results depending on whether the test point is approached with increasing or decreasing weight

or decreasing weight (Figure 6). Hysteresis issues in the instrument need to be determined with both increasing and decreasing points. When instrument is calibrated, the results are different with increasing and decreasing calibration points.

In a weighing test, when increasing or decreasing the load, it is important not to overshoot or undershoot — meaning that when the load is increased, you must approach each test point with increasing weight. If too much weight is added and then removed, the hysteresis information will be lost. Likewise, with decreasing points, make sure that each point is approached with decreasing weight. Obviously, in order to accomplish this, the test loads to be used should be well planned in advance.

Minimum weight test

The purpose of the minimum weight test is to find the smallest load that can be measured while still achieving reliable measurement results and fulfilling the accuracy requirements. When the measured value gets smaller, typically the relative error of the reading becomes higher. The weighing instrument should not be used to measure any loads smaller than the minimum load.

Minimum weight tests are not always required, but are common in some industries, such as pharmaceutical manufacturing.

Reference weights

When calibrating weighing instruments, it is recommended to use classified reference weights from metrological organizations such as NIST (U.S. National Institute of Standards and Technology; Gaithersburg, Md.; www.nist.gov) or OIML (Organisation Internationale de Métrologie Légale; Paris, France; www.oiml.org).

Reference weights should be handled in such a way that it does not change the metrological characteristics of the weights. The weights should kept off surfaces that could cause scratches and dirty surfaces that could introduce foreign materials. When cleaning weights, special attention should be paid to proper cleaning methods.

Smaller reference weights should always be handled with gloves, rather than with bare hands, to avoid any depositing grease or dirt from fingers onto the weights. Touching only with gloved hands will also help avoid warming the weights to a higher temperature than the surrounding environment.

When not in use, all reference weights should be stored in their own designated storage boxes. Weights should be stored so that only authorized personnel have access to them. Very large weights should be covered and stored in stable environmental conditions, where situations like moisture condensing on the weights' surface, for example, are avoided.

For reference weights, a distinction between nominal mass and conventional mass is made. Nominal mass is the designated mass of the given weight. When the weight is accurate enough, it is sufficient to use the nominal mass as the true value for legal verification. The conventional mass is the actual calibrated mass of the weight that has been corrected with any required local corrections. To make traceable calibrations, conventional mass should always be used.

Reference weights should be traceably calibrated regularly using an accredited calibration laboratory or a national calibration laboratory. Typically, the calibration period for reference weights is 1 to 5 years.

For more information on standard reference masses used for weighing calibration, see *Chem Eng.*, July 2023, p. 24.

Factors affecting calibration

There are several factors to note that may have an affect on the calibration of weighing instruments — especially smaller and more sensitive devices.

Local gravity. Gravity is slightly different in different locations around the globe. This is due to many factors, such as altitude (lower gravity at higher elevation), latitude (lower gravity closer to the equator), local geology and other factors.

Although gravity does not affect the mass of the weight on the scale, it does affect the force of the mass on the weighing instrument (Force = mass × acceleration due to gravity, *g*). And since a weighing instrument is measuring the force, the gravity affects the instrument's reading.

Local gravity differences may come into play if a weighing instrument is moved to a new location. In that case, it might need to be adjusted, depending on how accurate the instrument is and how much is it moved. Often, reference weights are calibrated in a different location than where they are used. There-

fore, the gravity difference needs to be considered when use the reference weights to calibrate and adjust your weighing instruments.

Air buoyancy. When weights are being used, air buoyancy results in a small force that reduces the force of the mass. So, in effect, air buoyancy lifts the weights up very slightly. The effect of air buoyancy depends on environmental conditions and on the differences of the density of the weights compared to air density. Because the effect of air buoyancy is relatively small, and does not change that much from day to day, it is not always considered.

Effect of convection. If the temperature of the weight differs from the environmental temperature, there will be an air convection around the weight. The wider the temperature differential, the larger the air convection will be. This convection will have a small effect on the indication of the weighing instrument.

For example, if the weight is colder than environment, the air convection around the weight will move downward facing the weighing instrument and cause small additional weight to the weighing instrument. The effect of convection is more relevant with high-accuracy instruments, although it is still relatively small.

Substitution loads

Substitution loads are items that can be used for help in calibration if the available weights are insufficient for the calibration. An example is the case where the calibration of a 1,000-kg weigh scale is required, but only one weight of 100 kg and two weights of 200 kg (total 500 kg) are available. To address this, the procedure would be to calibrate the first points up to 500 kg using the weights you have, then read the exact indication of the weighing instrument with the 500-kg load. The weights would then be removed and a substitution load would be placed on the weighing instrument until the indication matches readout when the 500-kg weights were on the scale. When the substitution load has the same measured weight value as the available accurate reference weights, you can then continue by adding the existing reference weights to the load surface that is still holding the substitution load to reach 1,000 kg target.

Calibration certificate

An essential part of calibrations is to document the results with a calibration certificate. The certificate includes the measurement results of the calibration (that is, the mass of the weights placed on instrument and the indication of the instrument).

The certificate should also include the total uncertainty of the calibration. Measurement values without related uncertainty do not tell very much about the measurement. The certificate should also include a clear description of the instrument being calibrated and the weights being used as reference. The calibration procedure that was followed should also be included. Environmental con-

FIGURE 7. Several factors can give rise to uncertainty when scales are used for normal weighing

ditions during the calibration should also be included in the certificate.

In summary, a calibration certificate should include the following information:

- Measurement results
- A unique certificate number
- User company name, address and identification
- Name, signature and company of the person who did the calibration
- Detailed information on the instrument that was calibrated
- Identification of the reference weights being used
- Identification of the calibration procedure being used
- Calibration date
- Environmental conditions
- Measurement uncertainty and its coverage factor
- Mention of the case when only a partial calibration was done
- A graphical representation of the calibration results if possible (useful visual component)

If the calibration is accredited, then the regulation will stipulate the contents of the certificate.

Uncertainty

In weighing instrument calibration, the uncertainty of the calibration should be known. Knowing the error of the scale indication at each calibration is not sufficient. Users must also know the uncertainty about the error found at each point of calibration. This section will discuss uncertainty at a more general level, rather than providing the details of how to carry out uncertainty calculations. Refs. *5* and *6* cover the uncertainty calculations in more detail.

There are several sources of uncertainty for the error in weighing instrument calibration, including the following (Figure 7):

- The masses of the weights are only known with a particular uncertainty
- Air convection causes extra force on the load receptor
- Air buoyancy around the weights varies according to barometric pressure, air temperature and humidity
- A substitute load is used in calibrating the scale
- Digital scale indications are rounded to the resolution in use
- Analog scales have limited readability
- There are random variations in the indications as can be seen in the repeatability test
- The weights are not in the exact center of the load receptor

The use of weighing instruments during routine operation can differ from use of the instrument during the calibration process. This also gives rise to additional sources of uncertainty. Examples of these differences include the following, for example:

- Routine weighing measurements involve random loads, while calibration is made at certain calibration points
- Routine weighing measurements are not repeated, whereas indications received through calibrations may be averages of repeated weighing measurements
- Finer resolution is often used in calibration than normal weighing
- Loading and unloading cycles in calibration and routine weighing may be different
- A load may be situated eccentrically in routine weighing
- A tare balancing device may be used in routine weighing
- The temperature, barometric pressure and relative humidity of the surrounding air may vary
- The adjustment of the weighing instrument may have changed

Standard and expanded uncertainties of weighing results are calculated using technical data of the weighing instrument, its calibration results, knowledge of its typical behavior and knowledge of the conditions of the location where the instrument is used. Calculating the uncertainty of the weighing results assists in deciding whether or not the accuracy of the weighing instrument is sufficient and how often it should be calibrated. ■

Edited by Scott Jenkins

References

1. EURAMET e.V. Technical Committee for Mass and Related Quantities, EURAMET Calibration Guide No. 18, Version 4.0, EURAMET e.V., Braunschweig, Germany, November 2015.
2. Butcher, T.G. and others, NIST Handbook 44 (2023 Edition) - Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, National Institute of Standards and Technology (NIST) Office of Weights and Measures, Gaithersburg, Md., 2022.
3. International Organization of Legal Metrology (OIML), OIML Standard R76-1, Non-automatic weighing instruments Part 1: Metrological and technical requirements – Tests, 2006 edition, OIML, Paris, France, www.oiml.org, 2006.
4. BSI Group, EN 45501:2015, Metrological aspects of nonautomatic weighing instruments, British Standards Institution, 2015.
5. European Co-operation for Accreditation (EA), EA-4/02, rev. 3, Evaluation of the Uncertainty of Measurement in Calibration, EA, Paris, France, www.european-accreditation.org, April 2022.
6. International Bureau of Weights and Measures (BIPM), JCGM 100:2008, Evaluation of measurement data: Guide to the expression of uncertainty in measurement, BIPM, Paris, France, 2008.

Additional resources:

- OIML, OIML R111: Weights of classes E1, E2, F1, F2, M1, M1-2, M2, M2-3 and M3, www.oiml.org.
- Council of the European Union, Directive 2009/23/EC,-Non-automatic weighing instruments, 2009.

Authors

Ned Espy, technical director, has been promoting calibration management with Beamex Inc. (2152 Northwest Parkway, Suite A, Marietta, Ga.; Email: ned.espy@beamex.com; Phone: 770-951-1927) for over 20 years. Espy has helped develop best practices for calibration, with a focus on pressure, temperature and multivariable instruments. He is a consistent editorial contributor to leading industry publications, and has received significant recognition within the automation industry. Today, Espy teaches calibration best practices and provides technical support to end users and the Beamex sales team.

Roy Tomalino has been teaching calibration management at Beamex (same address as above; Email: roy.tomalino@beamex.com) for over 20 years. He has taught on four different continents to people from over 40 countries. His previous roles include Technical Marketing Engineer and worldwide trainer for Hewlett Packard and Application Engineer with Honeywell. Today, Roy is a Beamex Calibration Evangelist. His primary mission is to demystify calibration and teach best practices.

Preventing Clogs in Low-Flow Coriolis Mass-Flow Controllers

In low-flow applications, Coriolis mass-flow controllers can be susceptible to clogging due to their small orifice. Filtration can solve most common clogging issues. Here are tips for filtration and clog prevention

Steve Kannengieszer
Brooks Instrument

IN BRIEF

Advanced material and catalyst research, as well as critical dosing and additive applications in the chemical process industries (CPI) require precise, accurate and reliable measurement and control of critical process-fluid flows. Manufacturers need low-flow liquid mass flow controllers that deliver repeatable results to ensure the exact amount of fluid is delivered.

For many low-flow liquid applications, Coriolis-type flowmeters and flow controllers provide superior accuracy independent of fluid properties, such as density or viscosity. However, even the most precisely engineered instruments can deliver faulty or unreliable results if there are fluid contamination and poor filtration preceding the Coriolis flowmeter or controller.

Understanding the sources of clogs and contamination in low-flow liquid-delivery systems, as well as proper filtration systems and techniques can help sustain accuracy and control in these applications.

FIGURE 1. In laboratory research and pilot plants, Coriolis mass flowmeters and controllers enable precise measurement of gas or liquid flowrates into a reactor and then the flow measurement of reactor output, to confirm the mass balance and optimize the process

Coriolis mass-flow measurement

A Coriolis-type flowmeter (Figure 1) is the only type of mass flow measurement and control device currently available that provides a direct mass-flow measurement. Its unique measurement principle is the foundation of Coriolis flowmeter accuracy: A direct mass-flow measurement occurs when a flow sensor device measures the mass flowrate of the fluid without needing to capture or measure additional fluid properties and incorporate those properties into the flowrate calculation.

There are several applications in chemical and petrochemical research, pilot-plant development and production manufacturing where direct flow measurement can help achieve superior results. In laboratory research and pilot plants, Coriolis mass flowmeters and controllers enable precise measurement of gas or liquid flowrates into a reactor and then the flow measurement of reactor output, to confirm the mass balance and optimize the process.

In production environments, these devices are used for precise ratio dosing of additives such as corrosion inhibitors or anti-foaming agents into the main process flow. Other applications include deposition of critical materials in fiber optic production, metal coating, glass coating and semiconductor wafer processing.

Contaminant sources, types of clogs

It is important to understand the different types of clogs and contaminants that can develop in liquid-delivery systems, their sources and how those contaminants can clog and disrupt the operation of low-flow liquid measuring and controlling instrumentation.

Solid particulate matter is a contaminant

TABLE1. DIMENSIONS OF FILTERS, ORIFICE AND PARTICLES

Filter, µm	Largest particle to pass through, µm	Typical orifice, µm	Typical orifice, in.
40	40	812.8	0.032
30	30	508.0	0.020
20	20	355.6	0.014
20	20	254.0	0.010
10	10	177.8	0.007
10	10	139.7	0.0055
1	1	101.6	0.004
1	1	76.2	0.003
1	1	50.8	0.002
1	1	25.4	0.001

that can pass through any opening greater than the particle's dimension. A spherical particle with diameter *d* will pass through any opening greater than *d*. For rod-shaped particles with diameter *d* and length *l*, where *l* > *d*, the particles will align themselves with the flow direction, so the characteristic dimension of the rod is still *d*.

Particle dimensions are usually measured in micrometers (microns; µm). A filter with a cutoff of 1 µm will allow particles with a size of 1 µm or less to pass through.

One of the most common types of solid contaminant comes from Teflon tape used to seal pipe joints. An easy way to eliminate this from a system is to use a flanged pipe seal instead of threaded connections. However, particles can also be introduced when one part of a system — such as an elastomeric O-ring or seal — comes in contact with a solvent that deteriorates the seal and introduces particles that can degrade meter performance.

Another common contaminant is moisture, which often comes from air that is already in the system. Many chemicals react with moisture to form solid deposits on surfaces or sticky gelatinous substances, leading to clogging.

Aqueous-based fluids that come in contact with bacteria deposited on surfaces exposed to air can also be a persistent source of clogs. Once water is flushed over this surface, the bacteria will pass through the system. When the system is shut down, bacteria will migrate to any carbon source and initiate a bacteria colony (biofilm). When the process flow resumes, the bacteria remains if not properly sanitized, and whenever there is no flow in the system, the bacteria grows until it clogs openings downstream.

While bleach-type additives in the fluid will kill the bacteria, they may not remove it from the surface. The only effective means of dealing with bacteria is filtration. An individual bacterial cell can be treated as a solid particle with a characteristic dimension of 0.45 µm. Most filter manufacturers suggest the use of a filter with a 0.2-µm cutoff.

There are two common locations for clogs: filters and valves. Filters can prevent some clogs, but depending on the contaminant's characteristics and diameter, the material may pass through.

The next location for a clog to occur is in the valve. Valves typically can clog in two ways. If the valve orifice is filled with material, it prevents the controller from achieving full-scale flow (Figure 2). The other way is when material is deposited on the orifice land and is sandwiched between the orifice land and the valve seat. This prevents the controller from fully closing or prevents the valve from controlling below certain flowrates. These two examples actually occur together in most cases.

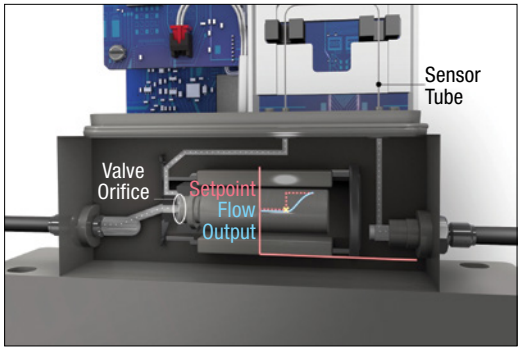


FIGURE 2. Shown here is a cutaway diagram of a Coriolis mass-flow controller. If the valve orifice becomes filled with material, the controller will no longer be able to achieve full-scale flow

Proper filtration

In any fluid system with conditions that risk contaminants and clog formation, filtration is the most effective way to remove solid particulate matter from a fluid. Clogs in filters and valves do more than just disrupt Coriolis device performance and precise low-flow fluid control. Equally hazardous, particles that pass through a controller eventually wind up in the production process, such as in a coating application or a chemical reactor. This will impact the final quality by deteriorating the performance of the manufactured product.

The goal of a filter is to trap these particles before they cause any interruption in either the process (clogging a valve orifice) or the final product (contamination in a coating). Once the particles have been trapped in the filter, the filter is to be discarded and then replaced with a fresh filter.

The best way to determine if the filter is trapping particulate matter is to monitor its pressure drop. When the pressure drop begins to rise, the paths in the filter are becoming blocked, preventing flow of fluids.

All flow controllers must have at least one filter upstream (except in very rare circumstances). The filter traps the particles that would otherwise clog the orifice. In particularly dirty liquid applications, prefilters are common and highly recommended (Figure 3). With some exceptions, prefilters have larger pore sizes. Some Coriolis flow controllers have a 50-µm prefilter preceding an inline filter of 10 µm. This allows the prefilter to catch the biggest particles (> 50 µm) and greatly extends the life of the inline filter.

Detection of clogs

The most common way to detect a clog is when the Coriolis flow controller cannot achieve the desired set point or reliably sustain a targeted flowrate, or when the controller cannot stop the flow.

However, a controller's inability to

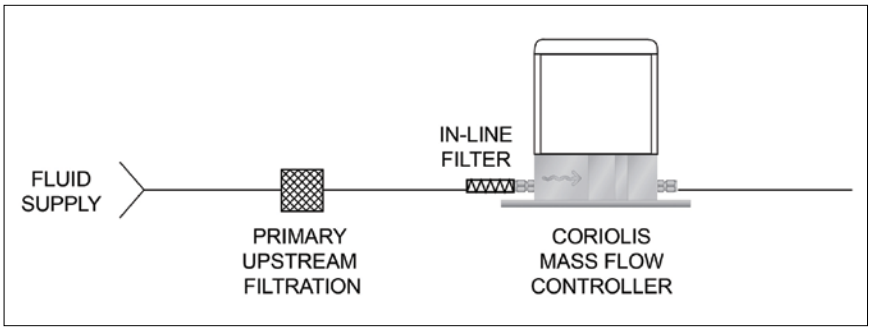


FIGURE 3. In particularly dirty liquid applications, prefilters are common and highly recommended

reach its setpoint may also be due to a lack of a proper inlet pressure. Therefore, before concluding that there is a clog, one should first confirm that the inlet pressure is sufficient.

In the event of a clog, the filter should be replaced (not simply removed). If the controller can now achieve set point, then the filter caught the clog, and it was time to replace the filter.

However, if the problem recurs a short time later and the controller again cannot achieve set point, it makes sense to filter the process fluid exiting the system with filter paper and inspect it under a microscope for particles. If particles are discovered after passing through prefilters, inline filters and the Coriolis flow controller, the process fluid should be further analyzed. Many liquids react chemically with the moisture found in air. The products of these reactions can then clog either the filter or the valve.

If the filter is not clogged but the controller cannot reach the established process set point, that indicates that the clog occurred after the filter. This is characteristic of clogs caused by a chemical reaction or O-ring/seal degradation. Check the controller documentation and the fluid's material safety data sheet to assess possible reactions with moisture, as well as to confirm whether the process liquids being transported are compatible with the seal materials and will not swell with the fluid. This is most common with elastomer O-rings and common solvents like toluene, tetrahydrofuran (THF), acetone and similar solvents.

Filter, orifice & particle sizes

Effective particle filtration requires an understanding of filter pore sizes and their relation to the size of particles and orifices in Coriolis flowmeters and controllers. Filters are typically categorized by the maximum size of particle that can pass through it, as measured in microns. Inline filters are typically offered in dimensions of 1, 10, 20, 30 or 40 µm.

Let's compare this to an orifice inside the valve of a low-flow Coriolis mass flow controller. The smallest orifice offered in this industry has an internal diameter (ID) of 0.001 in. This means that the orifice has an ID of 25.4 µm, which is much larger than the largest particle that passes through the 1-µm filter. Table 1 compares the filter, orifice and particle dimensions for a typical low-flow Coriolis mass flow controller application.

It is recommended that all orifices smaller than 0.007 in. use at least a 10-µm filter. The worst-case scenario would then be to use a 40-µm filter with a 0.01-in. orifice diameter (D) (254.0 µm). The ratio of the orifice diameter to the largest particle to pass through the filter would be 254.0/40 = 6.35. In other words, it would require more than six particles to jam into the orifice before the orifice would clog in one axis. However, the orifice is a hole with an area of $\pi(D/2)^2 = \pi(254.0/2)^2 = 50{,}670.7$ µm^2. Now the area occupied by the particle is $\pi(40/2)^2 = 1256.6$ µm^2. To completely block the orifice, there would need to be 50,670.7/1,256.6 = 40 particles jammed into it.

Table 2 shows the calculations of the number of particles that could pass through a given filter to completely clog the area of an orifice. It should be noted that these calculations are estimates of the number of particles needed to clog an orifice. They simply compare the

TABLE 2. NUMBER OF PARTICLES TO CLOG AN ORIFICE					
	Filter, μm				
Orifice, in.	1	10	20	30	40
0.001	645	6			
0.002	2,580	25			
0.003	5,806	58			
0.004	10,323	103			
0.0055	19,516	195			
0.007	31,612	316			
0.010		645	161	71	40
0.014		1,264	316	140	79
0.020			645	286	161
0.032			1,651	734	412

area of the orifice to the area occupied by a particle with a circular area. To be more precise, another term would have to be added to the equation to account for the packing efficiency, as shown in Figure 4. The white area in Figure 4 cannot be filled with the circles. So, the packing efficiency is less than 1. However, due to particle bridging across the orifice, the calculation becomes much more complicated. The numbers in Table 3 are simply presented to promote the understanding of the dimensions involved and are a close-enough approximation to communicate the information.

These calculations show that use of the appropriate size filter should, in almost all cases, prevent clogging of the valve orifice from solid particles. When clogging issues persist, plant and system operators should focus on other sources of clogging, such as chemical reactions with moisture or compatibility with O-rings.

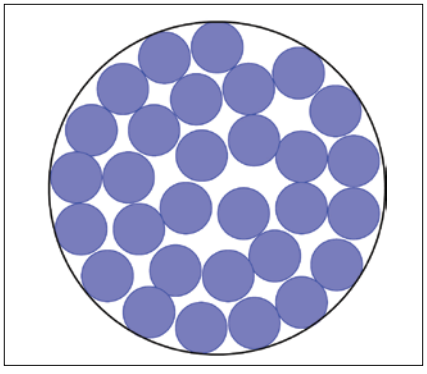


FIGURE 4. When calculating the number of particles leading to a clog, the packing efficiency would also need to be taken into account

Startup and shutdown

Many liquids are chemically reactive with water due to the polar nature of water. The most likely source of water in a flow system would be from the atmosphere (relative humidity). Therefore, to properly deliver these fluids, all moisture must be removed from the system. The rate at which these fluids react is dependent on the chemical nature of the fluid and the amount of moisture available for the reaction.

For low-flow Coriolis mass-flow controllers, it is important to understand that the controller is simply a valve designed to manage fluid flow. Once integrated into a system, the control valve orifice will always be the smallest opening the fluid will pass through. This makes it the most sensitive component to a fluid that has begun chemically reacting with moisture and potentially creating contaminants. In the event that the chemical reaction has begun but the contaminant passes through the controller, this material will end up in the final product, reducing yields and product performance.

There are two critical points during system operation when moisture can come in contact with the fluid: at startup and after shutdown. Preventing moisture from entering the system and setting the conditions for the creation of clogs depends on the specific conditions of the plant, how the system is constructed to deliver fluids and the vast array of fluids that might be transported.

At startup, the most practical way to remove moisture is to pull a vacuum to such a level as to remove the air in the system and evaporate all the moisture attached to surfaces in the system. Any small opening will restrict the vacuum pump's ability to pull the system down (of course, the entire system must be open, so the valve in the controller must be open).

Once the entire system is at a pressure below the vapor pressure of water, it will begin to evaporate. The system is not completely dry until the pressure of the system is stable. To determine this, the system is to be closed and the vacuum pump turned off. The pressure should be monitored for a period of time. If the pressure begins to increase, then either there is a leak or all the water has not yet evaporated. Either way, the system may not be dry enough for some fluids.

Since water will attach to any surface, and small openings limit the ability of the moisture to be removed from the system, filters must be carefully thought out. A filter has many small openings and far more surface area than the tubing or pipes in the system, so far more moisture can be contained within the filter than anywhere else in the system.

Pulling a vacuum on a filter may never completely remove the moisture. If the fluid is reasonably free of solid particulate matter, it may be advantageous to remove the filter from the system. Removing the filter from the system makes it more likely that all the moisture and the source of clogging will be removed. ■

Edited by Gerald Ondrey

All figures courtesy of Brooks Instrument

Author

Steve Kannengieszer is a global marketing director with Brooks Instrument (407 West Vine St., Hatfield, PA 19440-0903; Phone: 215-362-3608; Email: brooksam@brooksInstrument.com), focused on mass flow controllers for a variety of industrial markets. He has more than 34 years of experience in product development and management of instrumentation. Kannengieszer has a B.S.M.E degree from Drexel University and an M.B.A from Temple University.

Making the Invisible Visible with Electromagnetic Flowmeters

The patented technology to measure buildup can be used to optimize cleaning cycles and avoid unplanned shutdowns

Andrew Burg
Endress+Hauser Flow

To keep operations at peak efficiency, process systems must be kept as clean as possible. However, some of the normal byproducts of operating processes create deposits ranging from scales to sludge, precipitates and even metal deposits. These types of buildup can significantly reduce system efficiency, eventually causing plugging and unexpected downtime.

The flow measurement of an electromagnetic (EM) flowmeter is also directly affected by buildup in the measuring tube.

Electromagnetic flowmeters

To understand how buildup can be monitored, it is worthwhile to take a brief look at the operating principles of an EM flowmeter.

EM flowmeters are suitable for measuring the flow of electrically conductive fluids. They operate on the dynamo principle of Faraday's law of induction, which states that a metal rod moving in a magnetic field induces electrical voltage.

Inside the flowmeter are two field coils. The coils are used to create a constant magnetic field over the entire cross section of the measurement tube. Two electrodes that pick up electrical voltages are installed in the wall of the tube at a right angle to the electromagnetic field. If there is no flow in the tube, no induced electrical voltage is measured between the electrodes, as the electrically charged particles are equally distributed in the fluid.

When there is flow, the electromagnetic field generated by the two field coils exerts a force on the charged particles, separating the positive and negative charges. The induced voltage is picked up by the two measuring electrodes. This voltage is directly proportional to the velocity of the flow, and thus, with the cross-section area, to the flow volume.

The magnetic field is generated by a pulsed direct current with alternating polarity. This ensures a stable zero point.

This measuring principle is virtually independent of pressure, density, temperature and viscosity. Even fluids with entrained solids can be metered, for example, ore slurry or cellulose pulp. Because there are no moving parts, EM flowmeters are virtually maintenance-free.

However, in some cases, the nature of the fluids measured with EM flowmeters make them susceptible to buildup. The flow measurement of an EM flowmeter is directly affected by buildup in the measuring tube. While the reduction of the inner diameter leads to a miscalculation of the volume flow, the voltage picked up by the measuring electrodes is altered by the electrical properties of the buildup. These two effects are unequal in magnitude and can either add up or subtract, depending on process conditions.

Buildup measurement

With this in mind, a patented technology has been developed to measure buildup. The measurement is based on the fact that the electrical conductivity of the fluid and the buildup differ from one another. A voltage is applied to one of the measuring electrodes, either *E1* or *E2* (Figure 1). This creates a voltage distribution within the measuring tube, originating from the excited measuring electrode and the reference electrode (*REF*). This voltage distribution (*U2*) is picked up by the opposing measuring electrode and empty pipe detection (*EPD*) electrode. This measurement is repeated on the opposing electrodes and averaged to generate a stable signal.

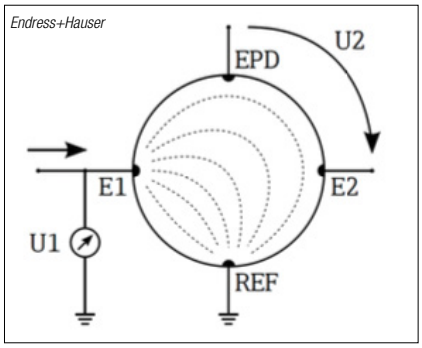


FIGURE 1. To measure buildup, a voltage distribution is generated within the measuring tube of the flowmeter

Buildup index

A voltage ratio (index) is then calculated, taking into consideration the voltage distribution in the measuring tube and the electrical conductivity of the passing fluid. This voltage ratio is computed and compared continuously, making it largely independent of conductivity and temperature changes of the passing fluid. Best results, however, are

FIGURE 2. Buildup or clogging of water wells due to iron hydroxide as well as manganese oxide deposition in groundwater is a common problem for operators of water-treatment plants

achieved in the measuring range of 20 to 100,000 µS/cm.

The calculated voltage ratio is subsequently normalized to the reference value of a clean pipe, which is determined during factory calibration. The resulting indexed value changes proportionally with the buildup thickness. This allows monitoring of an increase of buildup during operation, as well as a decrease of buildup during the cleaning process. The indexed value is displayed between 0 and 100%; whereby 0% corresponds to the reference values calibrated at production in a clean measuring tube, while 100% corresponds to the maximum detectable buildup — which is not necessarily a clogged tube.

Buildup is measured periodically, replacing a flow measurement sample with a buildup measurement at a defined sampling rate. This measurement period is adaptable to process conditions. For instance, a slow sampling rate could be used if buildup increases over a long period, for example, months or years, while a fast sampling rate increases the monitoring accuracy over shorter periods (hours or days). The buildup measurement is performed continuously and without process interruption.

As the measured buildup value is indexed, it is inherently process independent and can therefore be used in a wide range of applications and industries. Repeatability is highest with homogenous buildup, as layers of different types of buildup can lead to an incorrect interpretation of the voltage distribution. To derive a process-specific buildup thickness, the correlation between the buildup characteristics and the indexed value is necessary. By setting user-defined threshold values, the maintenance plan can be optimized, and the cleaning process shortened.

Buildup in water wells

A water-treatment plant in Germany faced the problem of unexpected downtime due to clogged water wells. Buildup or clogging of water wells due to iron hydroxide, as well as manganese oxide deposition in groundwater, is a common problem for operators (Figure 2). Iron(II) oxide dissolved in water comes into contact with oxygen and oxidizes to iron(III) oxide, which is water-insoluble and thus precipitates in wells, drainage shafts, pumps and pipes, as well as in any flowmeter. If users don't realize that buildup reaches critical levels, downtime due to unexpected interruptions of measurement signals or a clog in the process can occur. Moreover, iron hydroxide deposition causes additional pressure loss due to reduced pipe diameter. This in turn causes energy loss which leads to increased costs.

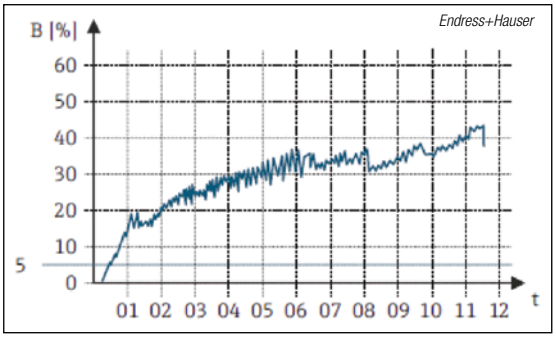


FIGURE 3. The continuous measurement of buildup, B, is plotted over a one-year time period

To solve these issues, a commercial EM flowmeter equipped with the patented buildup index monitoring technology was installed in the plant's water-extraction pipe at the well.

During two 12-month periods, the buildup of iron hydroxide in the user's application was continuously monitored (Figure 3). Every second month, the buildup thickness was measured and compared with the buildup index value. Buildup index reached 20% (3-mm or 0.12-in. thickness) in the second month and 40% (10-mm or 0.39-in. thickness) after 11 months. After 12 months, a cleaning was conducted and during another 12-month-period, the buildup index values and buildup thickness were compared. The results of the first year could be confirmed, proving that for the same fluid, the values are identical and therefore repeatable.

Besides other parameters, such as pump performance loss and lower flowrate, the operators can now monitor the buildup index to estimate the optimal cleaning time of the well to avoid unexpected downtime. Furthermore, the feature reduces the duration of the cleaning process since the operator knows exactly when the device is clean.

After evaluating the buildup during the first year, a more accurate maintenance plan for the well was established. The user was able to track and shorten the cleaning process. Additionally, the operator set a self-defined switch point that initiates planning of process maintenance in case buildup increases faster than expected. ■

Edited by Gerald Ondrey

Author

Andrew Burg is a product manager for electromagnetic flowmeters at Endress+Hauser Flowtec AG (Christoph Merian-Ring 4, 4153 Reinach, Switzerland; Phone: +41-61-71561-11; Email: info@endress.com). Burg holds a master of science, mechanical engineering degree from ETH Zurich.

Improving the Additive Manufacturing of Parts for Chemical Manufacturers

Optimizing the additive manufacturing of parts like actuators, regulators and valves will result in faster delivery, lower costs and improved performance for these crucial equipment components

Ali Babakr and Gerardo Gamboa
Emerson

Additive manufacturing (AM) technologies are benefitting the chemical process industries (CPI) in two main ways. First, existing parts that have been in service for decades and require replacement can often be produced using AM, with much faster lead times and at a lower cost than with conventional manufacturing techniques. Second, entirely new equipment designs are now possible — for example, unique or more complex valve trims — leading to improved performance (Figure 1).

Laser bed powder fusion (LBPF), a type of AM process, has opened pathways for producing complex actuators, regulators, valves and other related parts — each optimized for chemical processing applications — by removing many of the constraints associated with traditional manufacturing. Before LBPF, it was either impossible or impractical to produce such parts, but this has changed due to the freedom of design provided by AM.

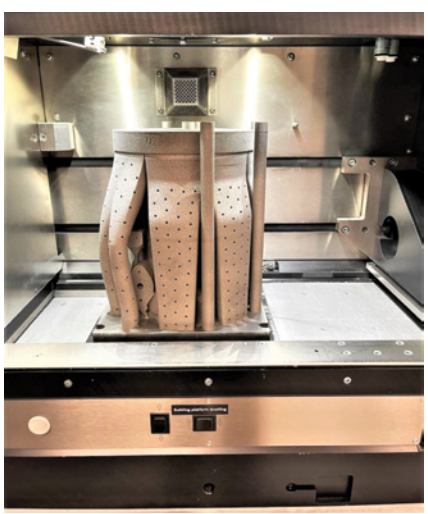


FIGURE 1. This prototype valve body was printed with hollow breakaway supports for development testing. Metal additive manufacturing allows for shorter lead times and quicker iterations during development, as compared to traditional fabrication methods. This facilitates faster overall development times and allows engineers to explore non-traditional designs

One example of how AM can lower costs is that new internal structures in regulator bodies and intricate geometries for valve internals are formed in one processing step. However, in some cases, parts produced using AM still require post-process machining due to the rough surface-finish inherent to LBPF techniques. This article details the optimization of LBPF parameters, including scanning speed, laser spot size, layer thickness, scan patterns and laser power, aiming to overcome such challenges related to quality for AM parts.

The new parameters were developed through a selective parameter matrix of laser power, hatch spacing (the separation between laser beams) and laser speed for 20-µm layers to improve the surface finish of parts made from 316L stainless steel and to reduce machining time from previously used 40-µm layers. Tensile bars were made to quantify the mechanical properties and surface finish of the 20-µm layer samples. The changes in physical properties were then correlated with the processing parameters to create a predictive trend analysis for future builds.

AM challenges

As previously mentioned, AM of metals offers a wide breadth of benefits compared to traditional manufacturing, such as faster production and the ability to create complex geometries, among many others. This makes AM a worthwhile investment for a range of industries, particularly as the technology becomes more affordable [*1*–*3*]. But many parts produced using LBPF still require machining when tight tolerances are an issue, such as with threads and bores, due to the nature of the rough surface finish of these parts [*4*]. As a result, there have been various attempts to try to shorten the overall manufacturing process of the finished part, either by the creation of hybrid AM systems with built-in computer numerical control capabilities [*5*], or by improving the properties of the material itself to make it more amenable to machining [*6*].

FIGURE 2. This photo shows a printed and stress-relieved cylinder (bottom), which was machined into the tensile bar shown at the top

The preferred approach in many cases is changing the processing parameters during LBPF, namely the layer height, to improve the surface finish of parts printed with 316L material. This is effective because a shorter layer height corresponds with a decrease in surface roughness, at the cost of an increased build time [*7*]. However, when changing the layer height of a build, the effect on the overall energy density of the build must be considered, because this is the parameter typically used to quantify the quality of solidification of a part [*2*, *3*]. This is shown in Equation (1) for volume energy density (*VED*), where *P* is the laser power (W), *v* is laser speed (mm/s), *h* is the layer height (µm) and *d* is the hatch spacing (mm):

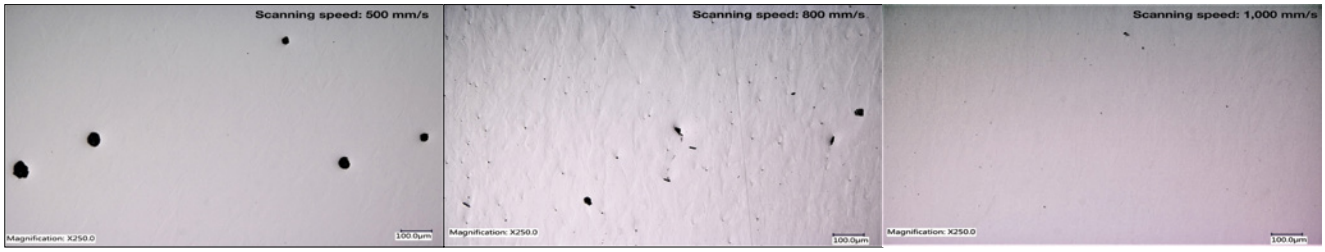


FIGURE 3. Representative micrographs of selective laser melting (SLM) samples at varying speeds of 500, 800 and 1,000 mm/s

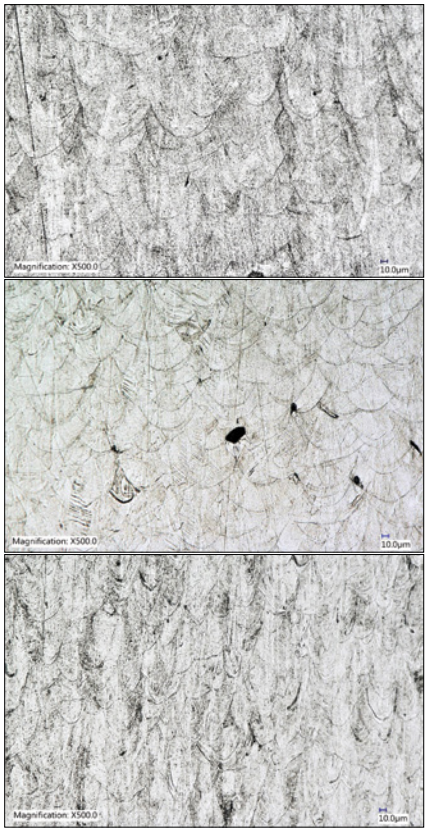


FIGURE 4. Optical micrographs of three samples show various defects, including deformation twinning, at different speeds and hatch-spacing values

$$VED = P/vdh \quad (1)$$

Laser scanning speed is related to the laser energy density applied to the molten pool of the material processed, which is specified as points per second as the beam travels across the print bed. These parameters can be modified to keep the volume energy density high. Through a trial-and-error process, the best combination of properties can be selected to create 316L stainless-steel parts that are mechanically strong, yet with low surface roughness of 20-µm, and with faster manufacturing time.

Part production details

For this exercise, parts were printed using 316L powder with a particle distribution of 5–50 µm. The samples were printed on an AM machine using a hard, recoated blade with a spot size of 80 µm and a 37-deg rotating scan pattern. Three cylindrical bars (A, B and C) of 18 mm x 85 mm were printed as shown in Figure 2 using the parameters shown in Table 1. The bars were then machined on a lathe to meet ASTM E8 standards governing the tensile testing methods for metallic materials.

Tensile tests were conducted using a load cell at room temperature and normal laboratory atmosphere, also following the ASTM E8 standard, with speed of 0.05 mm/mm. Stress-strain plots were created from the data to characterize the mechanical properties of each bar. Microstructural analysis was performed on a cross-section taken from tensile bars for each specimen, and samples were analyzed along their length for microstructure anomalies. Vickers hardness tests were conducted at room temperature using a hardness tester with a load of 500 g.

The impact of printing parameters

The objective of this work was to evaluate the predominant effect of varying AM printing parameters, namely scanning speed, laser spot size, layer thickness, scan patterns and laser power. These parameters — individually or combined — can influence the final microstructure of the product or part. It was also necessary to evaluate the manifestation of defects, such as dislocation, lack of fusion, cracks, pores (common in high laser energy density), anomalous microstructures (martensite formation) and balling effects.

Balling effects can be distinguished from unmelted particles only by metallography, which reveals solidification structure layers. This effect will occur when the molten layer does not wet the substrate due to surface tension. This leads to spheroidization of the liquid, resulting in a bead-shaped surface and preventing smooth layer deposition, thereby decreasing the density of the final part build [*3*, *8*].

The laser power and scan speed used in this investigation were suitable to prevent balling. Another method to alleviate the balling effect is decreasing powder layer thickness, as suggested by other researchers [*9–11*].

The material properties are clearly related to laser power and speed. An increase in laser power results in elevated temperature, leading to increased metal vapor pressure formed on the molten metal, thereby dislocating the material and creating pores (also called keyholes). Molten metal will try to fill the pores created after being melted again when the laser passes (Figure 3). No spatter effects or hot cracks were found within the material at the investigated power, scanning speed and hatch spacing.

Laser energy input directly determines the melt condition of metal powders and the flow of molten metal, both of which have a significant impact on the type and size of the defects in selective laser melting (SLM) process.

TABLE 1. PARAMETERS USED IN PART MANUFACTURING

Part	Layer height, mm	Hatch spacing, mm	Speed, mm/s	Power, W	VED, J/mm^3	Average pore size, µm
A	0.02	0.07	500	150	214.2857	53.5
B	0.02	0.1	800	125	78.125	34.2
C	0.02	0.05	1,500	150	100	31

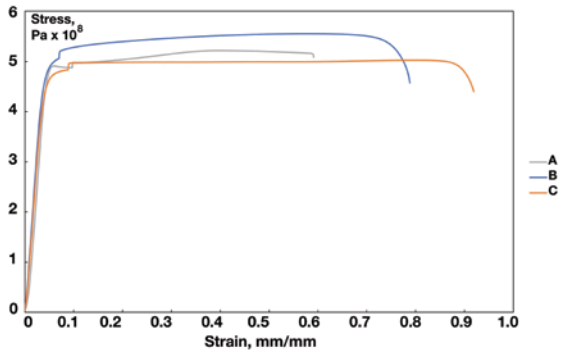


FIGURE 5. Tensile curves of the three test conditions (A, B and C) show a correlation between scan speed and ductility

The energy input to the material can be related to the main process parameters, such as laser power, scan speed, hatch spacing and layer thickness. At a low scan speed and a high laser power, the energy input is high, so more powders are melted at an elevated temperature, thus creating porosity defects.

Deformation twinning (Figure 4) and induced plasticity were revealed from metallography samples after tensile testing. It is believed that deformation twinning is responsible for the elevated plasticity, a positive effect, of the tested samples, regardless of the level of porosity found [*12–15*]. Deformation twinning, on the other hand, can have an adverse effect on ductility in other alloy systems [*16*].

As laser speed increases, the depth of penetration is reduced, along with the interlayer bonding between the layers, thereby increasing porosity [*12*]. Porosity reduction benefits the material fatigue life, as well as mechanical properties [*17*, *18*]. The subsequent tensile testing results (Figure 5) show that the build with the fastest print speed had the largest ductility (around 90%) before failure.

Findings

The influence of varying SLM parameters — namely hatch distance, scan speed and power — on the internal structure and porosity of the samples was investigated. Defects encountered included spherical porosities, irregularly incomplete fusion holes and cracks (indicating a lack of fusion). Spherical porosities were randomly distributed, while the lack of fusion was found to be between layers. All these issues are clearly affected by layer thickness, hatch spacing, scan speed and laser power. Deformation twinning was found to enhance plasticity, despite the presence of pores.

It was shown that processing at the selected high scanning speed is the most appropriate for minimizing porosity at the optimum hatch distance of 0.05 mm. Mechanical properties of the samples fabricated using varying strategies did not show significant differences in the yield strength and ultimate tensile strength values. These results will be used to complement upcoming work, which will facilitate improved quality and delivery time of AM parts, while maintaining strength, ductility and hardness.

For CPI companies, these benefits will result in improved performance of valves and related components,

along with lower prices and faster delivery times. Some of these benefits are already being realized due to AM, but further improvements will result when parts produced with AM require less machining and other processing. ■

Edited by Mary Page Bailey

References

1. Yadroitsev, I. and others, Strategy of manufacturing components with designed internal structure by selective laser melting of metallic powder, *Applied Surface Science*, Vol. 254, pp. 980–983, December 2007.
2. Ferro, P. and others, A modified volumetric energy density-based approach for porosity assessment in additive manufacturing process design, *The International Journal of Advanced Manufacturing Technology*, Vol. 110, September 2020.
3. Rombouts, M. and others., Fundamentals of selective laser melting of alloyed steel powders, *CIRP Annals — Manufacturing Technology*, Vol. 55, 2006.
4. Didier, P. and others, Post-processing of additive manufactured parts: a numerical strategy applied in maxillary implantology, *Matériaux & Techniques*, Vol. 110, September 2022.
5. Jiménez, A. and others, Powder-based laser hybrid additive manufacturing of metals: a review, *The International Journal of Advanced Manufacturing Technology*, Vol. 114, March 2021.
6. Pérez, J. and others, Machining stability improvement in LPBF, *CIRP Annals*, Vol. 72, 2023.
7. Patil, D., Effects of Increasing Layer Thickness in the Laser Powder Bed Fusion of Inconel 718, Arizona State University, Tempe, Ariz., Vol. 8, 2019.
8. Kruth, J. and others, Selective laser melting of iron-based powder, *J. Mater. Process Technol.*, Vol. 149, pp. 616–622, June 2004.
9. Gu, D. and Shen, Y., Balling phenomena in direct laser sintering of stainless-steel powder: Metallurgical mechanisms and control methods, *Materials & Design*, Vol. 30, September 2009.
10. Osakada, K. and Shiomi, M., Flexible manufacturing of metallic products by selective laser melting of powder, *International Journal of Machine Tools and Manufacture*, Vol. 46, pp. 1,188–1,193, September 2006.
11. Antony K. and Rakeshnath T., Study on selective laser melting of commercially pure titanium powder, *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol. 233, September 2018.
12. Penn, R., 3D printing of 316L stainless steel and its effect on microstructure and mechanical properties, Montana Tech University, 2017.
13. Dengcui Y. and others, Twinning behavior in deformation of SLM 316L stainless steel, *Materials Research Express*, Vol. 9, September 2022.
14. Pham, M., Dovgyy, B. and Hooper, P., Twinning induced plasticity in austenitic stainless steel 316 L made by additive manufacturing, *Materials Science and Engineering: A*, Vol. 704, pp. 102–111, September 2017.
15. Yuhai Y. and others, Mechanism of high yield strength and yield ratio of 316 L stainless steel by additive manufacturing, *Materials Science and Engineering: A*, Vol. 744, pp. 773–777, January 2019.
16. Shiyang L. and others, Effects of deformation twinning on the mechanical properties of biodegradable Zn-Mg alloys, *Bioactive Materials*, Vol. 4, pp 8–16, 2019.
17. Cherry, J. and others, Investigation into the effect of process parameters on microstructural and physical properties of 316L stainless steel parts by selective laser melting, *Int. J. Adv. Manuf. Technol.*, pp. 869–879, September 2014.
18. Hukpati, K. and others, Effect of printing parameters on the structure and high strain rate deformation behavior of additively manufactured 316L stainless steel, *Materials Science and Engineering: A*, Vol. 853, September 2022.

All figures courtesy of Emerson

Authors

Ali Babakr is a senior principal materials engineer for research and development at Emerson (ali.babakr@emerson.com). Babakr previously held various positions with Emerson and other companies as a subject matter expert dealing with metallurgical and failure evaluation, material selection and corrosion studies. He has field experience in the petroleum and petrochemical industries, and he participates in various industry subcommittees. Babakr holds M.S. and Ph.D. degrees in metallurgy from the University of Idaho and a B.S. degree in chemistry from Huston-Tillotson University in Austin, Tex.

Gerardo Gamboa is a materials engineer with the research and development team at Emerson (gerardo.gamboa@emerson.com). He started his professional career with Emerson as an additive manufacturing co-op student, while also attending the University of North Texas (UNT) in Denton, Tex. to obtain his M.S. degree in materials science and engineering. Gamboa has previous research experience as an undergrad and graduate researcher at UNT in semiconductor materials, batteries and composite materials. He is currently pursuing his Ph.D. at UNT in materials science and engineering.

Electrical Safety: NFPA 70B is a Driving Force for Resilience and Reliability

A new industry standard relating to the safe operation of electrical equipment can help manufacturers transition from an irregular maintenance schedule to a safer, more prescriptive regimen

Douglas Beck
Schneider Electric

We used to need to change our motor oil every 3,000 miles. The only way we were able to track progress was with the car's odometer, with little visibility into oil quality or levels between mechanic visits. Now, modern vehicles are equipped with advanced computer systems that can precisely report when it is time for an oil change and even alert you about dropping oil levels. Industrial settings, particularly those in the chemical process industries (CPI), require a similar system for assets, where equipment health is paramount to safe, resilient and efficient operations.

A turning point arrived in January 2023 when the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) officially adopted its Recommendation for Electrical Equipment Maintenance (70B) as an industry standard, making 70B compulsory. The standard aims to accelerate the transition of manufacturing and other industrial firms' reactive, "every-3,000-miles" model to a proactive approach to maintenance for electric equipment, empowered by data and optimized processes.

Revamping maintenance plans

Not only is NFPA 70B mandatory, but it also appoints local authorities having jurisdiction (AHJs), including organizations like the Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov), to enforce the standard. Creating an oversight system will make it more challenging for firms to continue with lax policies and reinforce a culture of safety and preventative maintenance. The major benefit of the NFPA's change is improved plant safety.

FIGURE 1. Maintenance activities can pose safety risks, including fires, for electrical equipment. NFPA 70B aims to help organizations craft equipment-maintenance strategies that ensure plant and personal safety

While the National Electrical Code (NEC or NFPA 70) governs safe equipment installation, and NFPA 70E outlines how to safely operate electrical equipment, 70B codifies thresholds for whether equipment is working properly. Because electrical fires and other safety issues tend to occur during maintenance — during which systems are configured abnormally — 70B is the crucial third component of the plant-safety trifecta (Figure 1). NFPA 70B will help chemical manufacturers contend with three major obstacles to ongoing plant safety: aging equipment, increasingly complex power systems and the loss of expertise.

For installed equipment, manufacturer maintenance guidelines take precedence. However, the average lifespan of assets in the chemicals industry is 30 to 40 years [*1*], and many assets have either become obsolete since installation or now lack support from the original equipment manufacturer (OEM). Even properly installed equipment that is still supported will deteriorate over time once it is in place, especially when maintenance schedules are irregular, or equipment checks are done poorly.

Even as equipment ages, manufacturers continue to modernize as internal and external pressures force industrial firms to become more efficient [*2*]. On an industrial scale, introducing operational efficiency requires implementing increasingly complex power systems. Modern systems incorporate everything from microgrids to backup power generation, all converged under a single pane of control software. Every new power-system component represents another potential point of failure. In addition to these changes, as new equipment comes in to replace or integrate with older assets, employees are departing in droves, taking valuable knowledge with them [*3*]. New hires do not always have the requisite experience or skill level to replace departing seasoned expertise. As a result, facilities that once employed many specialized maintenance engineers may now only have one person responsible for

maintaining everything.

NFPA 70B addresses each of these intertwined challenges. It forces manufacturers to be more diligent in their maintenance schedules, use technology to continuously monitor asset health and develop a robust maintenance plan. Documenting and adhering to a regulated maintenance plan gives manufacturers with older equipment careful instruction for complex systems and a backstop for industry talent loss.

Navigating turbulent waters

While 70B and NFPA as a whole are concerned chiefly with safety, the new standard will also help manufacturers enhance resilience and reliability. Improving these operational facets should help CPI firms overcome challenges to productivity and output that they currently face.

CPI manufacturers currently report decreased production levels and stagnant new-order volume relative to the first quarter of 2023 [*4*]. They also cite a decrease in raw-materials inventory levels and a large increase in labor costs. Along the supply chain, rising transportation costs and freight disruptions have caused nearly 90% of chemical manufacturers to modify operations [*5*]. These factors, combined with government and investor pressure to address net-zero decarbonization goals, are squeezing manufacturers, forcing them to seek out as much additional operational efficiency as possible.

FIGURE 2. Digitalizing electrical diagrams can help to ensure plants' compliance with industry safety standards

When other preventable disruptions, such as fires or accidents occur, they add downtime to the already-challenging operating environment. Analysts and researchers estimate the high cost of unplanned downtime — often resulting from equipment failure — can range anywhere from $10,000 to $250,000 per hour [*6*]. Large CPI organizations can run into losses of millions of dollars daily when production assets stop working altogether [*7*].

Chemical products' need for specific temperatures and careful handling make it much more difficult for plant owners to restart operations after an incident. Chemical manufacturers have indicated that it often takes them up to two weeks to restart operations after downtime. For instance, a paint manufacturer requires precise environment control to maintain plant consistency. Bottling plants or automotive paint shops may emit vapors into other process equipment, potentially causing corrosion or other complications.

It can be challenging to document all the intertwined complexities of chemical manufacturing environments. However, 70B necessitates robust planning and digital monitoring to ensure compliance, forcing manufacturers to keep detailed, more transparent, track of their plant's processes.

Robust maintenance practices

Turning the Recommendation for Electrical Equipment Maintenance into a standard will also push manufacturers to adopt helpful digital technologies. For example, 70B requires that manufacturers have robust documentation of their plants' electrical systems. The documentation must include up-to-date single-line diagrams. Traditionally, these diagrams are difficult to keep updated, which introduces more points of failure into safety procedures.

When manufacturers undertake a new capital project and add to the facility, they tend to only add onto existing line diagrams, rather than update the entire drawing. When someone performing asset maintenance only has a partially updated diagram or a physical print on the wall from a decade ago, it is easy to see how issues may "slip through the cracks." Keeping static files up to date isn't something that operating expenditure teams have budgets for, so poor documentation persists.

Employing digital twin technology keeps firms' diagrams updated and compliant with 70B (Figure 2). Intelligent single-line diagrams (iSLDs) are digital models of a plant's electrical distribution network. Unlike their static counterparts, iSLDs include information about asset functionality and system behavior. Manufacturers can use these data to model usage, create visualizations, simulate different scenarios and validate the system's performance for safety, reliability and efficiency.

Intelligent and dynamic single-line diagrams integrate seamlessly with other operational systems. Organizations can continuously update and re-validate the drawing as needed, without having to recreate the diagram from scratch. Most importantly, digital twins, like iSLDs, serve as a single source of truth for manufacturers, preserving changes to power systems, even when institutional knowledge departs via retirement. When maintenance workers come to inspect assets, the digital twin populates the line diagram and other asset-health information on a mobile device.

Digital twins are just one method that chemical manufacturers can use to help develop robust processes for change management. To further bolster maintenance processes, manufacturers can integrate other digital tools, such as continuous thermal-monitoring platforms. These innovative technologies provide a near real-time view of asset health to help identify potential problem spots outside of scheduled maintenance. Modern monitoring platforms help remove any guesswork remaining in asset maintenance.

Many legacy monitoring platforms provide metering information about energy flow, telling operators where power is going within the plant. However, these platforms do not provide details beyond descriptive direction-based information. Cutting-edge monitoring platforms collect and analyze data about a litany of factors. They can inform operators whether equipment is aging too quickly, operating at too high of a temperature or with poor electricity quality, and inform operators when equipment needs more frequent maintenance.

What compliant plants can gain

NFPA 70B forces manufacturers to constantly evaluate the functionality of their equipment against three benchmarks: criticality of the asset to the rest of the system; the environment surrounding the asset; and the asset's physical condition. Maintenance personnel give each asset a score for all three factors. If an electrostatic dip tank for automotive paint primer receives a score of 1 in all three categories, the plant operator can elect to maintain the tank at longer intervals (of up to five years). If the tank has begun to corrode because of acidic vapors, it may receive a score of 2 or lower, requiring maintenance every 12 to 36 months.

In this capacity as a safety mechanism, 70B ensures that CPI plants adhere with robust maintenance plans. As a forcing function

for adopting digital technology to assist with maintenance and monitoring, the standard will also help manufacturers achieve needed resilience and reliability.

Moreover, 70B leads manufacturers from maintaining assets on an irregular schedule without visibility into asset health between checks to a predictive and prescriptive maintenance regimen. Without a robust, data-informed maintenance plan, neglected assets must be replaced more often, leading to extended downtime and unplanned capital expenditures.

The robust documentation, planning and technology that 70B requires make things much easier. Monitoring data might warn operators that a substation between maintenance checks is overheating. Rather than replace the asset after it burns out, the manufacturer can instead build housing with air conditioning around the substation to cool it down, avoiding a plant shutdown and asset replacement.

In effect, 70B equips manufacturers with a comprehensive approach that increases safety measures and takes advantage of digital technologies. By embracing such innovation, modern systems encourage a culture of proactive maintenance. The result is not only safer plant operations, but also more resilience and reliability — the boost needed to withstand the current climate of uncertain supply chains, reduced raw materials inventories and increased costs. ■

Edited by Mary Page Bailey

References

1. International Energy Agency (IEA), Typical lifetimes and investment cycles in key heavy industries, July 2020.
2. Martin, R., A Thorough Assessment of Digital Transformation in the Chemical Industry, ABI Research, February 2023.
3. Falkenroth-Naidu, K., others, A new operations formula for the chemicals sector, McKinsey & Co., January 2023.
4. American Chemistry Council (ACC), Survey: Chemical Producers Concerned About Challenging Regulatory and Economic Environment, September 2023.
5. ACC, ACC Member Supply Chain Report (H2 2022), March 2023.
6. Zheng, H., others, Advancing from Predictive Maintenance to Intelligent Maintenance with AI and IIoT, The 3rd International Workshop on Artificial Intelligence of Things (AIoT), in conjunction with the 26th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2020), September 2020.
7. Dilda, V., others, Manufacturing: Analytics unleashed productivity and profitability, McKinsey & Co., August 2017.

Images courtesy of Schneider Electric

Author

Douglas Beck (Email: douglas.beck@se.com) is Schneider Electric's U.S. industrial automation services leader, a role in which he leads a diverse team that utilizes data and analytics to provide actionable insights. He has over 25 years of experience in the power services industry, working to improve the safety, reliability and resiliency of facility power distribution systems. Beck began his career as a nuclear operator onboard U.S. Navy Submarines and has since held leadership positions in several OEM service organizations.

Advertisers Index

See bottom of opposite page for advertising sales representatives' contact information

Classified Index March 2024

FOR ADDITIONAL NEWS AS IT DEVELOPS, PLEASE VISIT WWW.CHEMENGONLINE.COM

March 2024; VOL. 131; NO. 3

Economic Indicators

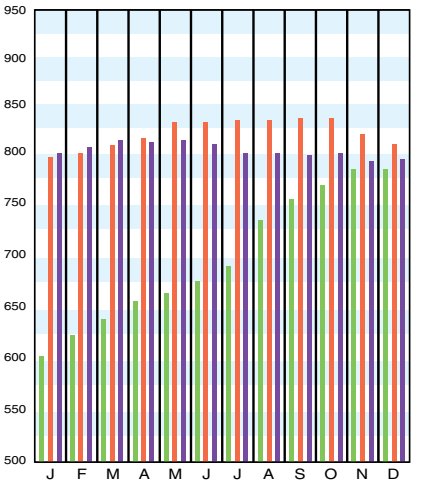
2021 2022 2023

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX® (CEPCI)

(1957–59 = 100)	Dec. '23 Prelim.	Nov. '23 Final	Dec. '22 Final
CE Index	790.8	789.2	802.9
Equipment	992.0	990.3	1,016.1
Heat exchangers & tanks	808.7	804.8	840.8
Process machinery	1,018.7	1,014.7	1,031.4
Pipe, valves & fittings	1,320.2	1,331.4	1,427.2
Process instruments	563.7	560.3	558.5
Pumps & compressors	1,484.9	1,484.5	1,332.4
Electrical equipment	807.3	804.4	790.7
Structural supports & misc.	1,105.4	1,096.4	1,122.5
Construction labor	374.8	373.9	359.0
Buildings	802.0	797.2	794.2
Engineering & supervision	314.9	314.9	311.8

Annual Index:
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8
2022 = 816.0

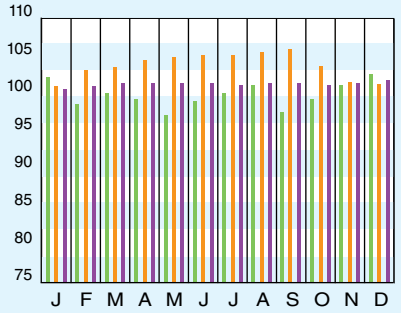


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

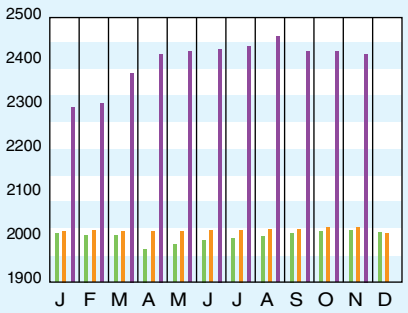
CURRENT BUSINESS INDICATORS

	LATEST			PREVIOUS				YEAR AGO		
CPI output index (2017 = 100)	Dec. '23	=	98.9	Nov. '23	=	98.8	Oct. '23	=	99.4	Dec. '22	=	96.6
CPI value of output, $ billions	Nov. '23	=	2,397.7	Oct. '23	=	2,398.4	Sept. '23	=	2,464.9	Nov. '22	=	2,483.8
CPI operating rate, %	Dec. '23	=	78.6	Nov. '23	=	78.5	Oct. '23	=	79.1	Dec. '23	=	77.4
Producer prices, industrial chemicals (1982 = 100)	Dec. '23	=	302.4	Nov. '23	=	308.9	Oct. '23	=	315.8	Dec. '23	=	332.2
Industrial Production in Manufacturing (2017 =100)*	Dec. '23	=	99.1	Nov. '23	=	99.0	Oct. '23	=	98.8	Dec. '23	=	97.9
Hourly earnings index, chemical & allied products (1992 = 100)	Nov. '23	=	228.9	Oct. '23	=	224.0	Sept. '23	=	227.4	Nov. '22	=	209.5
Productivity index, chemicals & allied products (1992 = 100)	Dec. '23	=	90.5	Nov. '23	=	90.6	Oct. '23	=	91.0	Dec. '23	=	87.0

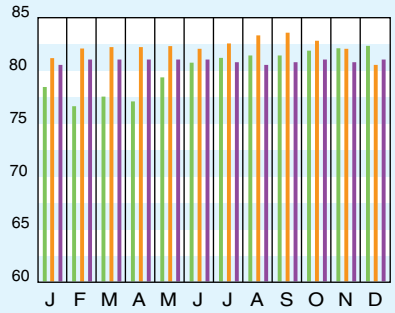
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for December 2023 (the most recent available) edged slightly higher than the previous month's value, reversing a trend of decreasing values for the past six months. Within the overall CEPCI value, small upticks were observed in the Equipment, Buildings and Construction Labor subindices. The Engineering & Supervision subindex was flat. The current CEPCI value now sits at 1.5% lower than the corresponding value from December 2022. Meanwhile, the Current Business Indicators (middle) show the CPI output index rose by a tiny margin in December 2023, while the CPI value of output index fell slightly in November 2023.